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APPENDIX C: ENVIRONMENT, SAFETY, AND HEALTH

The purpose of this appendix is to discuss the environment, safety, and health (ES&H) programs at Lawrence Livermore National Laboratory (LLNL), including the Livermore Site and Site 300. Of particular importance is the support this appendix provides to discussions of the related parts of Chapters 4 and 5 of the *Site-wide Environmental Impact Statement for Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement* (LLNL SW/SPEIS).

Section C.1 discusses the regulatory requirements for ES&H programs with which LLNL must comply. Section C.2 discusses the organizations of LLNL that have ES&H responsibilities. This section also discusses LLNL's implementation of the Integrated Safety Management System (ISMS) and the Work Smart Closure Process in support of ES&H programs. Section C.3 discusses occupational exposures to radiation, toxic materials, and other industrial hazards arising from the normal operations of facilities. Section C.4 discusses environmental monitoring programs and the impact of releases of radioactive and toxic materials from normal plant operations. The potential impact to workers and members of the general public from hypothetical accidents is discussed in Appendix D, with transportation accidents discussed in Appendix J. Section C.5 discusses the methods and protocols used by LLNL to assure the quality of these programs.

The line management of LLNL is responsible for providing safe working conditions for LLNL employees, for limiting exposure of the general public in the vicinity to hazardous and radioactive materials, and for implementing environmentally sound operating practices to ensure environmental compliance. The Hazards Control Department, the Environmental Protection Department, and the Health Services Department at LLNL assist in meeting these responsibilities.

C.1 REGULATORY REQUIREMENTS

The U.S. Department of Energy (DOE), in response to Defense Nuclear Facility Safety Board (DNFSB) Recommendation 95-2 (DOE 1995a), committed to implementing an ISMS across the complex by issuing an implementation plan in April 1996 and, subsequently, DOE Safety Management System Policy 450.4 (DOE P 450.4) in October 1996. This policy, along with DOE Acquisition Regulation clauses 970.5204-2 and 970.5204-78 (49 CFR Part 970), requires contractors to follow ISMS objectives, guiding principles, and functions, and to describe the approach for implementing and tailoring Integrated Safety Management to the contractor's site/facility or activities. The LLNL ISMS description provides a formally approved institutional structure for Integrated Safety Management developed by LLNL using written guidance and continued detailed interaction and coordination from the National Nuclear Security Administration (NNSA) and DOE. The description contains the LLNL institutional approach for the incorporation and implementation of DOE P 450.4 to "…systematically integrate safety into management and work practices at all levels so that missions are accomplished while protecting the public, the worker, and the environment." Upon final approval by NNSA, this policy establishes the agreement on the content and processes for Integrated Safety Management implementation and continued utilization at LLNL (LLNL 2003cc).

The ISMS is an approach to defining the scope of work, identifying the hazards, establishing controls, performing the work, and concluding with feedback and improvement. The system defines a process for identifying, planning, and performing work that provides for early identification of hazards and associated control measures for hazards mitigation or elimination. The ISMS process also forms the basis for work authorization and both internal and external assessment that provides a continuous feedback and improvement loop for identifying shortcomings and successes for incorporation into subsequent activities.

ISMS controls for workplace hazards are specified in a safety and health framework based upon a set of written policies, rules, orders, and standards. LLNL, University of California, and DOE used the necessary and sufficient process to select a comprehensive set of standards that define the ES&H requirements for LLNL into Contract 48 (LLNL 2002db) in accordance with Clause 5.5(f): "Environmental, safety, and health requirements applicable to this contract may be determined by a DOE approved process to evaluate the work and associated hazards and identify an appropriately tailored set of standards, practices, and controls…"

Applying the necessary and sufficient process requires the adherence to DOE policy, "Authorizing Use of the Necessary and Sufficient Process for Standards-Based Environment, Safety and Health Management," DOE P 450.3 of January 25, 1996, and the DOE Manual, "The Department of Energy Closure Process for Necessary and Sufficient Sets of Standards," DOE M 450.3-1 of January 25, 1996. These documents define the process and its required elements. During the establishment of the necessary and sufficient process at DOE, it was determined that the resulting standards should be called Work Smart Standards.

The Work Smart Standards are important as input to the ISMS and as a key operational component for developing controls. In the relationship between the standards and ISMS, the standards provide general and specific requirements that are tailored to LLNL activities and the ISMS establishes the structure and implementation mechanisms for using these Work Smart Standards as the basis for performing work safely.

As changes occur, there will be new knowledge, technologies, and issues. With these, there will be new laws, regulations, and standards. Consequently, there is a need to periodically review and update the Work Smart Standards in Contract 48 using a formal process. A formal change control process for the standards utilizes the principles of the necessary and sufficient process. The change control process provides a system to keep these standards up to date and includes provisions for addressing new and special situations that might arise from any source.

More information on the LLNL ISMS and Work Smart Closure Process will be discussed later in this appendix. A complete listing of Work Smart Standards requirements, including the necessary and sufficient groupings, may be found at http://labs.ucop.edu/internet/comix/contract/LLNL/wss_llnl.pdf.

C.2 ORGANIZATIONS TO ADDRESS ENVIRONMENT, SAFETY, AND HEALTH

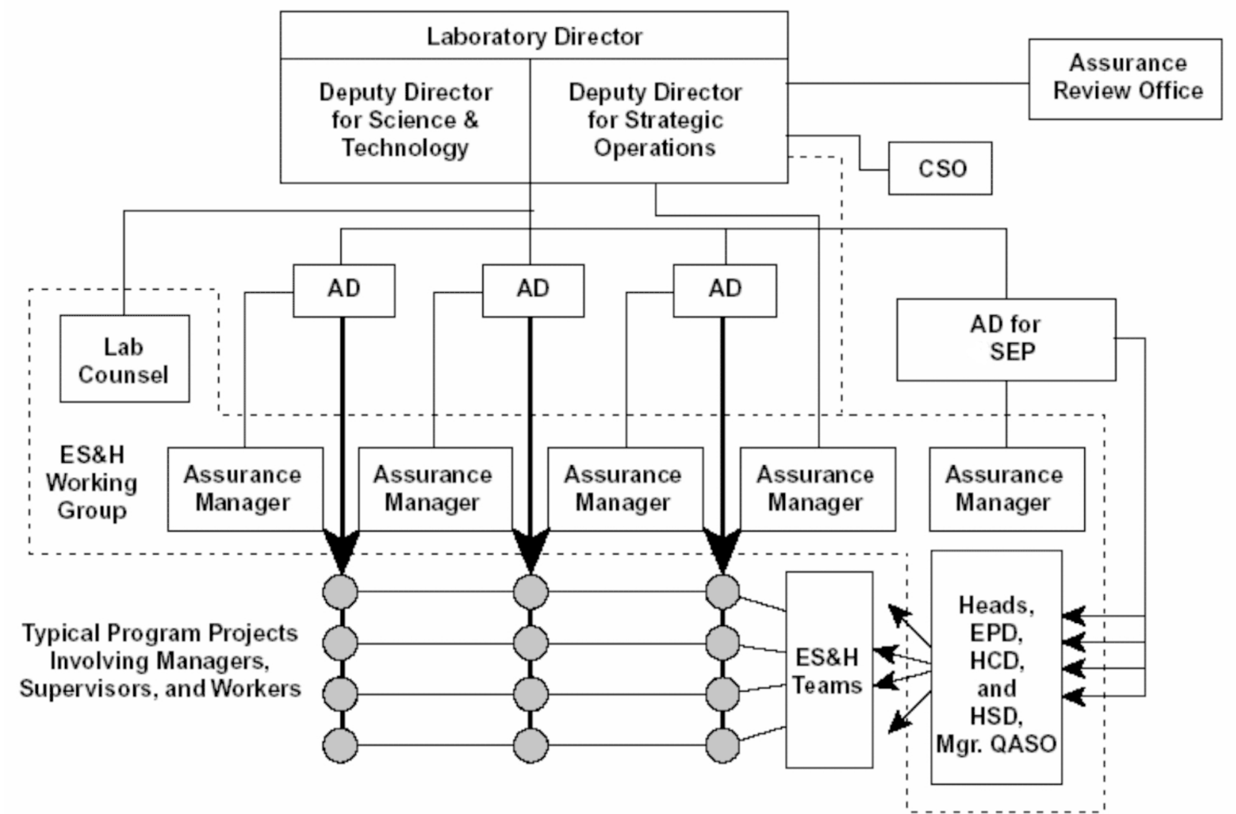
C.2.1 Lawrence Livermore National Laboratory Organizations and Responsibilities

Each associate director and program leader at LLNL is responsible for ensuring that work activities under their direction are conducted in a manner that produces high quality results, preserves environmental quality, and protects the health and safety of the workers and the public. The Safety and Environmental Protection Directorate provides ES&H and other technical support services to all directorates, primarily through the Hazards Control, Environmental Protection, and Health Services departments.

The management and execution of the ES&H Program is a distributed task, i.e., each LLNL line organization integrates applicable elements of the ES&H Program into its work activities. Some administrative offices with significant ES&H-related responsibilities, e.g., the Office of the Laboratory Counsel and the Office of Contract Management, presently report to the Director's Office. Other organizational elements provide technical support and advisory, assurance, and oversight functions. The management structure for the ES&H Program provides for the following key responsibilities:

- Implementation of the ES&H Program is a line management responsibility that is delegated from the director to the associate directors, and then flows through each associate director's line/program/discipline management chain to each employee.
- The Deputy Director for Operations advises the Director on ES&H policies and institutional issues, with input from the ES&H Working Group and other ES&H committees, and oversees the effectiveness of activities and programs to implement these policies.
- ES&H institutional planning and technical support to the directorates are provided by the Associate Director/Safety Environment Protection Directorate.
- Assurance that ES&H Program implementation is performed at the directorate level by an assurance manager who, reporting to the associate director, also provides independent oversight.
- Institutional independent oversight of the ES&H Program implementation by the directorates is performed by the Assurance Review Office.

The basic relationships and groupings of positions and organizational elements contributing to ES&H management at LLNL are depicted in Figure C.2.1–1. This management structure is used for the full range of activities—construction, startup, routine operations, maintenance, emergencies, and demolition. The figure illustrates LLNL's formal lines of decisionmaking authority and responsibility and outlines the hierarchy of the organizational elements (LLNL 2003k).

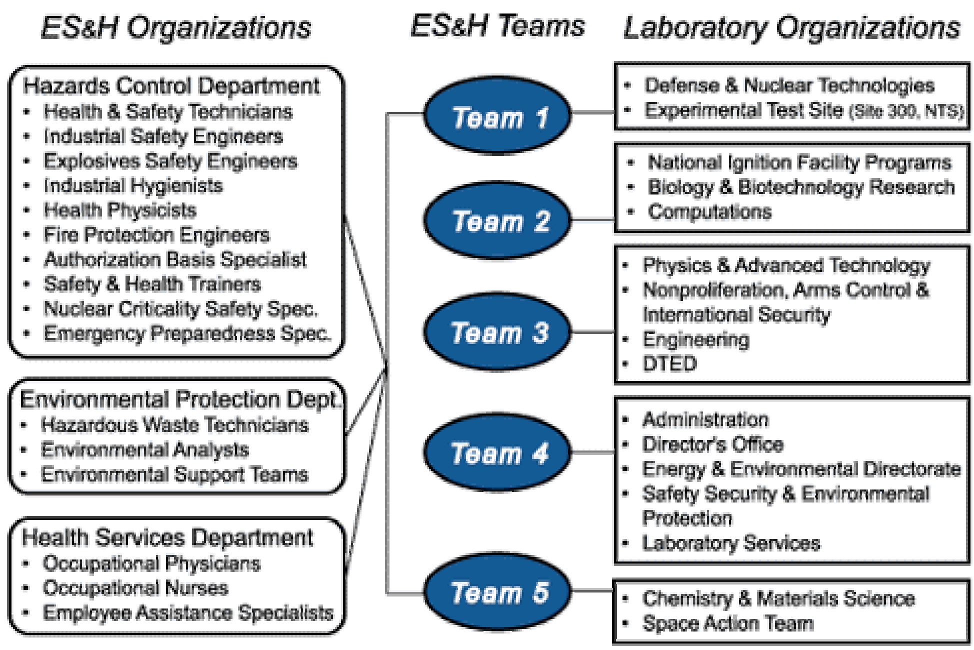


AD = Associate Director; CSO = Council on Strategic Operations; EPD = Environmental Protection Department; ES&H = Environmental, Safety, and Health; HCD = Hazards Control Department; QASO = Quality Assurance Support Office.

FIGURE C.2.1–1.—*Organizational Structure and Connections at Lawrence Livermore National Laboratory for Operations and Environmental, Safety, and Health Management*

The associate directors have the responsibility and authority for conducting LLNL's programmatic work and for applying and fulfilling LLNL's ES&H policies in the performance of that work. Associate directors must be aware of statutory, regulatory, and contractual ES&H requirements applicable to their operations and facilities. In meeting their obligations, each associate director can simultaneously function in one or more of the following four operational functions: program, payroll, facility, and services. For many mission projects, the Program Associate Director is also the Payroll, Facility, and Services Associate Director. Authorities for the different operational functions vary, but the Program Associate Director has the primary responsibility.

Figure C.2.1–1 also shows the ES&H Working Group composition and how it is connected into the entire organizational structure of LLNL. Figure C.2.1–2 depicts the support structure by which ES&H organizations, subject matter experts, and teams interface with all LLNL programs and organizations. The composition of each team is tailored to the work of specific programs and organizations. An ES&H Team can be configured with a wide range of disciplines. In addition, experts from outside LLNL can be called in when needed. ES&H Teams are assigned to each Directorate and the Director's Office. Details of the ES&H Teams' responsibilities are included in the ES&H Manual (LLNL 2000i).



Source: LLNL 1998a.

FIGURE C.2.1–2.—*Environment, Safety, and Health Support Structure*

The ES&H Working Group (which reports to the Deputy Director for Operations) is composed of assurance managers from each directorate, the four heads of the ES&H and quality assurance technical support organizations, and representatives from the Legal Office (as nonvoting members). The Deputy Director for Operations selects the chairperson of the group on a calendar year basis.

The ES&H Working Group reviews and makes recommendations for approving most institutional-level ES&H implementation documents containing requirements and guidance, which are developed by the ES&H technical support organizations. These documents are based upon contractually required laws, regulations, and standards. The final documents are approved and signed by the Deputy Director for Operations prior to publication in the ES&H Manual (LLNL 2000i). There are four standing subcommittees: Environmental, Institutional, Nuclear Facilities, and Hazards Control, Health Services, and Emergency Services, that support the ES&H Working Group in fulfilling its obligations by analyzing and reviewing specific ES&H issues. The subcommittees comprise Working Group members, program representatives, and subject-matter experts.

The Council on Strategic Operations is a committee of associate director-level managers that reviews and advises the Deputy Director for Strategic Operations on institutional cross-cutting operational issues. Approximately half of their time is spent on ES&H items having major impact on LLNL.

ES&H expertise and technical support to LLNL line organizations is provided by four functional organizations reporting to the Associate Director/Safety and Environmental Protection Directorate (LLNL 1996b): Hazards Control Department, Environmental Protection Department, Health Services Department, and Quality Assurance Office.

In general, these organizations are responsible to the Associate Director/Safety and Environmental Protection Directorate for performing the following functions:

- Interpret DOE directives and, in collaboration with LLNL Counsel, ES&H laws and regulations
- Develop or revise LLNL policies for review by the ES&H Working Group and Senior Management Council and approval by the Director
- Develop policy implementation guidance for review and approval by the ES&H Working Group
- Publish ES&H and Quality Management/Quality Assurance manuals, guidelines and other supplemental information on how to satisfy ES&H and quality assurance requirements
- Develop and conduct ES&H and assurance program personnel training
- Review operations and procedures, and advise on appropriate protective measures and controls
- Assist line organizations with preparing safety, environmental, and quality management documentation
- Monitor operations and work sites to provide management with the information needed to help maintain a minimal-risk work environment
- Provide services and direct support to line organizations to aid them in meeting their ES&H requirements
- Provide health services, such as examinations, treatment of occupational and minor nonoccupational injury and illness, consultations, agent-specific health surveillance, and fitness-for-duty evaluations
- Provide ES&H review of new facilities design

C.2.1.1 *Organization of the Hazards Control Department*

The head of the Hazards Control Department reports to the Associate Director/Safety and Environmental Protection Directorate, who is responsible for providing assistance to line managers for occupational health and safety programs and environmental protection programs at LLNL. The Hazards Control Department provides assistance to line managers for radiological and nonradiological occupational safety (LLNL 2002bk).

The Hazards Control Department is comprised of three divisions: the ES&H Teams Division, the Safety Programs Division, and the Emergency Management Division.

The ES&H Teams Division has the primary responsibility of providing environmental, safety and health support to LLNL programs and organizations. The five ES&H Teams provide services and support programmatic and overhead organizations to help them ensure a safe and healthy workplace. Each team services specific program areas and consists of safety and health discipline members and health and safety technologists. In addition, environmental analysts from the Environmental Protection Department and Health Services Department personnel are matrixed into the teams.

The Safety Programs Division supports LLNL by providing the institutional leadership and direction of those safety programs necessary to maintain a safe and healthy workplace for staff and the surrounding community. This is accomplished by offering technical analysis and support, training programs, analytical services, and guidance to LLNL on how to comply with applicable rules, regulations, orders, and standards.

The Safety Programs Division works to ensure that consistent safety programs are developed and implemented for LLNL. This division maintains safety programs in authorization basis, chemical and biological safety, occupational safety, criticality safety, and radiation safety, and provides safety education and training. This division also provides other institutional functions, such as chemical safety officer, respirator program administrator, electrical safety officer, internal dosimetry program coordinator, pressure safety coordinator, non-ionizing radiation safety officer, x-ray safety coordinator, and other institutional functions as assigned by the Hazard Control Department Head. Additional institutional services provided include the safety glasses office; respirators shop; whole body counter; hand-held instrument maintenance and calibration; chemical and radiological analyses and full dosimetry services; training services covering; other computer-based and classroom instruction, and coordination and development of the combined ES&H Manual and the health and safety portion of the manual.

The Emergency Management Division responds to emergency incidents on LLNL and Sandia National Laboratories/California properties to ameliorate the effect of incidents so as to limit the further loss of life, extension of injuries, and loss of property to LLNL, its employees, and the surrounding community. This division houses the institutional function of Laboratory Fire Marshal. In support of this mission, the division performs emergency dispatch and response for security emergencies, fire prevention and control, and liaison with surrounding emergency agencies.

C.2.1.2 *Organization of the Environmental Protection Department*

As the lead organization at LLNL for providing environmental expertise and guidance on operations at LLNL, the Environmental Protection Department is responsible for environmental monitoring, environmental regulatory interpretation and implementation guidance, environmental restoration, environmental community relations, and hazardous waste management in support of LLNL's programs. This department prepares and maintains environmental plans, reports, and permits; maintains the environmental portions of the ES&H Manual; informs management about pending changes in environmental regulations pertinent to

LLNL; represents LLNL in day-to-day interactions with regulatory agencies and the public; and assesses the effectiveness of pollution control programs. These functions are organized into three divisions within the department: Operations and Regulatory Affairs Division, Radioactive and Hazardous Waste Management (RHWM) Division, and the Environmental Restoration Division.

The Environmental Protection Department monitors air, sewerable water, groundwater, surface water, soil, sediments, vegetation, and foodstuff, as well as direct radiation; evaluates possible contaminant sources; and models the impact of LLNL operations on humans and the environment. In 2002, 11,877 samples were taken, and 212,689 analytes were tested. The type of samples collected at a specific location depends on the site and the potential pollutants to be monitored (LLNL 2003c).

A principal component of the Environmental Protection Department's mission is to work with LLNL programs to provide guidance and expertise so that operations can be conducted in a manner that assures compliance with regulatory guidelines. As requested by programs, Environmental Protection Department helps LLNL programs manage and minimize hazardous, radioactive, and mixed wastes; determines the concentrations of environmental contaminants remaining from past activities; cleans up environmental contamination to acceptable standards; responds to emergencies in order to minimize and assess any impact on the environment and the public; and provides training programs to improve the ability of LLNL employees to comply with environmental regulations.

The Operations and Regulatory Affairs Division currently consists of six groups that specialize in environmental compliance and monitoring and provide LLNL programs with a wide range of information, data, and guidance to make more informed environmental decisions. This division prepares the environmental permit applications and related documents for submittal to Federal, state, and local agencies; acts as the liaison between LLNL and regulatory agencies conducting inspections; tracks chemical inventories; prepares *National Environmental Policy Act* (NEPA) documents for DOE and NNSA and conducts related field studies; oversees wetland protection and floodplain management requirements; coordinates cultural and wildlife resource protection and management; facilitates and provides support for the pollution prevention and recycling programs; teaches environmental training courses; coordinates the tank environmental compliance program; conducts compliance and surveillance monitoring; provides environmental impact modeling and analysis, risk assessment, and reporting; and develops new methods and innovative applications of existing technologies to improve environmental practices. The Operations and Regulatory Affairs Division also assists in responding to environmental emergencies such as spills. During normal working hours, an environmental analyst from the Operations and Regulatory Affairs Division Environmental Operations Group responds to environmental emergencies and notifies a specially trained Environmental Duty Officer. Environmental Duty Officers are on duty 24 hours a day, 7 days a week, and coordinate emergency response with LLNL's ES&H Team and other first responders or environmental specialists (LLNL 2003l).

All hazardous, radioactive, medical, and mixed wastes generated at LLNL facilities are managed by RHWM in accordance with local, state, and Federal requirements. RHWM processes, stores, packages, solidifies, treats, and prepares waste for shipment and disposal, recycling, or discharge to the sanitary sewer. As part of its waste management activities, RHWM tracks and documents the movement of hazardous, mixed, and radioactive wastes from waste accumulation areas, which are located near the waste generator, to final disposition; develops and implements approved standard operating procedures; decontaminates LLNL equipment; ensures that containers for waste shipment meet the specifications of the U.S. Department of Transportation and other regulatory agencies; responds to emergencies; and participates in the cleanup of potential hazardous and radioactive spills at LLNL facilities. RHWM prepares numerous reports, including the annual and biennial hazardous waste reports required by the state and Federal environmental protection agencies. RHWM also prepares waste acceptance criteria documents, safety analysis reports, and various waste guidance and management plans. RHWM meets regulations requiring the treatment and disposal of LLNL's mixed waste in accordance with the requirements of the *Federal Facility Compliance Act* (Public Law 102-386). The schedule for this treatment is negotiated with the State of California and involves developing new onsite treatment options as well as finding offsite alternatives. RHWM is responsible for implementing a program directed at eliminating the backlog of legacy waste, which is waste that is not presently certified for disposal. This effort includes a large characterization effort to identify all components of the waste and a certification effort that will provide appropriate documentation for the disposal site.

The Environmental Restoration Division was established to evaluate and remediate soil and groundwater contaminated by past hazardous materials handling and disposal processes, and from leaks and spills that have occurred at the Livermore Site and Site 300, both prior to and during LLNL operations. This division conducts field investigations at the Livermore Site and Site 300 to characterize the existence, extent, and impact of contamination. This division also evaluates and develops various remediation technologies, makes recommendations, and implements actions for site restoration. The Environmental Restoration Division is responsible for managing remedial activities, such as soil removal and groundwater extraction, and for assisting in closing inactive facilities to prevent environmental contamination. As part of its responsibility for *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) (42 U.S.C. §9601 et seq.) compliance issues, the division plans, directs, and conducts assessments to determine the impact of past releases on the environment and the restoration activities needed to reduce contaminant concentrations to protect human health and the environment. This division interacts with the community on these issues through environmental community relations. Public workshops are held annually and information is provided to the public as required in the community relations plans. To comply with CERCLA groundwater remedial actions at the Livermore Site, the Environmental Restoration Division has to date designed, constructed, and operated 5 fixed groundwater treatment facilities and associated pipeline networks and wells, 20 portable groundwater treatment units, 2 catalytic dehalogenation units, and 3 soil vapor extraction facilities. In 2001, the Environmental Restoration Division operated 4 fixed, 19 portable, 2 catalytic reductive dehalogenation, and 2 soil vapor treatment units. The division also installed an electro-osmosis system to improve its ability to remove contaminants from fine-grained sediments. At Site 300, the division has designed, constructed, and operated 3 soil vapor extraction facilities and 11 groundwater extraction and treatment facilities. In addition, the division has capped and closed four landfills and the explosives rinse water lagoons and burn pits, excavated and closed numerous wastewater disposal sumps; and removed contaminated waste and soil to prevent further impacts to groundwater at Site 300. The Environmental Restoration Division is actively designing, testing, and applying innovative remediation and assessment technologies to contaminant problems at the Livermore Site and Site

300. The division also provides the sampling and data management support for groundwater surveillance and compliance monitoring activities (LLNL 2003l).

The Environmental Protection Training Program provides LLNL workers the appropriate training support to ensure that they have the knowledge, skills, and abilities to competently, safely, and effectively carry out the environmental protection responsibilities of their work assignments. In 2001, this program provided nearly 9,000 hours of environmental protection training to LLNL workers involved in science related work at LLNL. The Environmental Protection Training Program also provided an additional 3,000 hours of specialized training to LLNL environmental professionals involved with the management of waste and other environmental protection activities. The environmental training developed and delivered to LLNL workers during 2001 addressed the requirements of NEPA, the *Resource Conservation and Recovery Act*, the *Superfund Amendment and Reauthorization Act*, Occupational Safety and Health Administration, and other Federal and State of California regulatory requirements. Training subjects included hazardous waste management; low-level waste generation and certification; transuranic waste generation and certification; spill prevention, control, and countermeasures; pollution prevention; and other related topics. The training program staff is supported in the development and delivery of training by environmental protection subject matter experts from the three Environmental Protection Department divisions. The divisions provide the assessment and interpretation of training to be given to LLNL workers and to internal Environmental Protection Department specialists. In addition, the divisions supply subject matter experts and personnel who are trained and qualified to be instructors. The staff consists of trained professionals and technical and administrative personnel familiar with the various environmental regulations and requirements and cognizant of LLNL operations requiring environmental protection training (LLNL 2003l).

C.2.1.3 *Health Services Department*

The Health Services Department provides an occupational health program that meets regulatory requirements and professional standards to assist in providing a safe and healthful work environment. The Health Services Department provides:

- Treatment for occupational and minor non-occupational injuries and illnesses
- Emergency care, stabilization, and transfer to local emergency room
- Return-to-work assistance after injuries and illnesses
- Multidisciplinary worksite inspections regarding health hazards and environmental conditions; medical surveillance, qualification and fitness for duty examinations
- Educational programs designed to address health concerns in the workplace
- Health promotion services
- Physical therapy for occupational injuries and illnesses
- Decontamination and treatment for chemical or radiological exposures

- Employee assistance services

LLNL implemented the Return-to-Work Program in November of 1999 to better serve the needs of employees who suffer work- or nonwork-related injuries or illnesses resulting in lost worktime or medical restrictions. This program is an integral part of the LLNL Integrated Safety Management program. The intent of the program is to implement a system for returning employees to work quickly and safely after injury or illness, and to improve LLNL's capability of identifying and appropriately managing temporary and permanent disabilities. Specifically, the Return-to-Work Program objectives are:

- Provide support to employees in their recovery from injuries or illnesses by providing temporary, modified, or alternate assignments
- Provide enhanced support to employees following both occupational or non-occupational injuries or illnesses by better coordinating programs, processes, and services
- Minimize the amount of absence and resulting impact to both the employee and the organization due to these injuries or illnesses
- Implement effective disability case management

C.2.2 Integrated Safety Management System and Work Smart Standards

On March 3, 1999, Secretary of Energy Richardson directed all DOE and contractor employees to put Integrated Safety Management in place by September 2000 (Richardson 1999a). LLNL previously met its first major milestones when it delivered the first versions of the Superblock description to the NNSA Oakland Operations Office in October 1998 and the LLNL institutional description in December 1998. In parallel, the LLNL Work Smart Standards were completed and confirmed in March 1999. They were signed and incorporated into Contract 48 on August 5, 1999. Further accomplishments were made with the Superblock ISMS Phase I and II Verification completed in September 1999 and the NNSA Oakland Operations Office approval of the Superblock ISMS description on September 30, 1999, contingent on addressing two items, which have been done, and the process proceeds for finalization. The second version of this institutional ISMS description addressing NNSA Oakland Operations Office comments, including LLNL items to make it more complete and understandable, was completed in October 1999. The verification of the LLNL institutional ISMS was successfully completed in September 2000. The Superblock ISMS description and the LLNL site-wide ISMS descriptions are reconciled (LLNL 2003cc).

The creation and development of Integrated Safety Management in NNSA operations has evolved over time. The *Price-Anderson Amendments Act* in 1988 (Public Law 100-408) is seen as a start in Integrated Safety Management along with the fundamental changes brought about with the end of the Cold War. Actions by the Defense Nuclear Facilities Safety Board in their Recommendations 90-2 and 92-5, site visits by the Tiger Teams, and DOE Nuclear Safety Order upgrades led to increased attention and formalization in DOE operations. The DOE initiation of the N&S Standards in 1995, which became the Work Smart Standards, continued that process. Defense Nuclear Facilities Safety Board Recommendation 95-2 combined several prior recommendations and considerations in reports and became the primary driver for Integrated

Safety Management, which is contained in the DOE Implementation Plan for Defense Nuclear Facilities Safety Board Recommendation 95-2 (DOE 1995a). The DOE Safety Management System Policy, DOE P 450.4, of October 15, 1996 (LLNL 2002b), presented the structure to "provide a formal, organized process whereby people plan, perform, assess, and improve the safe conduct of work." It was "institutionalized through DOE directives and contracts to establish the Department-wide safety management objective, guiding principles, and functions." The applicable Department of Energy Acquisition Regulation amendment followed in 1997 and Clause 6.7, "Integration of Environment, Safety, and Health into Planning and Execution," became part of the University of California DOE contract for LLNL on October 1, 1997. Direction and guidance on Integrated Safety Management continues to be developed and refined as the process proceeds with Secretary Richardson's Memorandum of March 3, 1999, on "Safety-Accountability and Performance," (Richardson 1999a) and the revised ISMS Guide, DOE G 450.4-1A, of May 27, 1999 (DOE G 450.4), being recent major items.

The LLNL ISMS description (LLNL 2003cc) provides a formally approved institutional structure for Integrated Safety Management developed by LLNL using written guidance and continued detailed interaction and coordination from NNSA and DOE. It contains the LLNL institutional approach for the incorporation and implementation of the DOE Safety Management System Policy, DOE P 450.4 to "…systematically integrate safety into management and work practices at all levels so that missions are accomplished while protecting the public, the worker, and the environment." Upon final approval by NNSA, it establishes the agreement on the content and processes for Integrated Safety Management implementation and continued utilization at LLNL.

The description identifies the core requirements that provide the foundation for safety management at LLNL. These requirements implement DOE's seven guiding ISMS principles and five core functions along with LLNL's Fundamental Guiding Principle.

DOE Seven Guiding Principles
1. Line management responsibility for safety
2. Clear roles and responsibilities
3. Competence commensurate with responsibilities
4. Balanced priorities
5. Identification of safety standards and requirements
6. Hazard controls tailored to work being performed
7. Operations authorization
DOE Five Core Functions
1. Define the scope of work
2. Analyze the hazards
3. Develop and implement hazard controls
4. Perform work within controls
5. Provide feedback and continuous improvement

Lawrence Livermore National Laboratory Fundamental Guiding Principle

Each worker, supervisor, and manager is directly responsible for ensuring his or her own safety and promoting a safe, healthful, and environmentally sound workplace and community.

The above fundamental requirements provide the necessary specificity and detail for Integrated Safety Management implementation through LLNL documentation. The ES&H Manual is the principal institutional mechanism for implementation. The LLNL Fundamental Guiding Principle differs somewhat from the Occupational Safety and Health Administration General Duty Clause (clause 5a (1) of the *Occupational Safety and Health Act* of 1970, which is contained in an LLNL Work Smart Standards (LLNL 2002db). This states that that it is the employer's duty to provide a safe and healthy workplace. These two concepts go hand-in-hand.

Core Requirements

The comprehensive set of core requirements developed and presented in the description has the following principal elements:

Accountability

Regarding the LLNL Fundamental Guiding Principle, all workforce members are held accountable for meeting LLNL's ES&H requirements. Accountability is established and enforced through the following primary means:

- Communicate ES&H expectations to employees
- Reinforce expectations through timely verbal feedback
- Implement formal appraisal and salary actions for each employee, annually
- Award and recognize notable contributions to ES&H
- Use corrective action in cases of employee misconduct

Safety Responsibility

Ultimately, management is responsible for safety.

Management Chain

Organizations that authorize work identify a management chain for each work activity. Such organizations identify the individuals serving in the chain, such as first-level supervisor (Responsible Individual) up to responsible Associate Director. The management chain has clear roles, responsibilities, and authorities for managers, supervisors, and workers. The chain has direct control over the funding of the work activity. It exists for all LLNL operations down a clear line of funding and ES&H responsibility. The chain has full responsibility for implementing DOE's seven guiding principles and five core functions. Ultimately, it ensures that individuals perform work safely.

Subcontractors

LLNL's commitment to safety and Integrated Safety Management is formally extended to subcontractors and subcontract employees for whom LLNL has safety responsibility. Safety requirements are to be incorporated into all subcontracts and flowed down to lower-tier subcontractors, as appropriate.

Graded Approach and Tailoring

At LLNL, ISMS provides for a graded approach; i.e., different levels of rigor and formality, when applying controls commensurate with the hazards involved. To complement this, tailored controls address the hazards, satisfy the applicable requirements, and provide protection to the public, workers, and the environment.

Work Planning and Authorization

Work would be planned, reviewed, and authorized before the activity begins. An appropriate prestart review is conducted to validate satisfaction of the safety requirements. Once the work begins, it is appropriately controlled. Workers are responsible for adhering to the safety controls, and responsible individuals ensure the work is performed according to the defined work controls). Responsible individuals ensure that workers have access to and knowledge of governing procedures and work controls for any given activity.

Feedback and Improvement

Work activities would be monitored to ensure that governing procedures and safety documents are being followed. Workers are to inform responsible individuals of safety concerns and opportunities for improvement. A worker can stop work if there is an unsafe or unapproved condition. Each directorate develops and operates a safety self-assessment program guaranteeing a proactive approach to safety and improve safety performance. Directorates are also responsible for root-cause analysis and correction of safety-related problems. After an activity is completed, lessons learned are shared to enhance operational safety and facilitate cost effectiveness.

Integration

Integration of program and safety planning from the director down to individual workers is attentive to the institution/facility/activity process. Basic to LLNL integration and operations is the ES&H Manual and incorporation of its ISMS fundamentals. Worker involvement is critical to Integrated Safety Management, thus an important integration direction is a formalized upward involvement of workers as well as top down through the institution/facility/activity process. In this context, all work activities are to be performed according to the provisions of the ES&H Manual with the assistance of ES&H subject matter experts and ES&H Teams. Horizontal integration across the directorates is accomplished through many established groups.

Directorate Implementation Plans

To establish the flow down of ISMS requirements from institutional requirements to the working level, each directorate has an ISMS implementation plan or other established directorate plans or documents that succeed the implementation plan to satisfy the requirements specified in the description. Separate directorate implementation plans are appropriate because each directorate has unique programmatic missions with different types of facilities, technical work, and hazards. Directorate implementation plans or succeeding documents shall reference specific implementing provisions for each of the core requirements established in the description. When uniform practices are mandated, each directorate references the specified implementing provisions. Directorate implementation plans define the organization's document hierarchy and the safety roles, responsibilities, and authorities for each position level within the organization. Initial directorate implementation plans are subject to institutional review to assure that the requirements established in the description are satisfied. The directorate implementation plan may be the chosen continuing operating document or it may be the transition document; thus, appropriate succeeding documentation may be necessary. This is specifically noted or added in particular sections for completeness and emphasis.

Environment, Safety, and Health Manual

To be in line with the increased formalization brought about by Integrated Safety Management, LLNL has assembled broadly-used institutional ES&H documents into a formal document structure called the ES&H Manual (LLNL 2000i). This new comprehensive manual consolidates many documents into one convenient online package. It includes what was formerly the Health & Safety Manual and the Environmental Compliance Manual. LLNL performs work to meet the requirements of the new manual. Its requirements are based on the Work Smart Standards identified for specific LLNL work and associated hazards. With the implementation of Integrated Safety Management, employees must understand the latest ES&H requirements and their responsibilities.

Communications and Training

Integrated Safety Management communications has the long-term goal of helping to change LLNL's safety culture. The strategy behind long-term communications and training is to position the concept of workplace safety alongside those of technical excellence and quality work in everyday LLNL life. This is done by placing the subject of safety and key safety messages in front of employees frequently, using a variety of media, making sure employees have appropriate training, and by involving employees in identifying and solving safety problems.

Many different communication tools and approaches would be used to engage employees at all levels. Planning includes campaigns to promote awareness of specific concerns such as eye protection, expanded development and communication of lessons learned, promotion of the online ES&H Manual, communications guidance for supervisors, computer-based information sources, and special events. Feedback mechanisms will be used to identify problems and successes as Integrated Safety Management continues to mature.

The application of a best management practices is providing the framework for future communication. The best management practices were derived from a laboratory study of industrial and scientific sites known for good safety records, from laboratory-led focus groups, and from experiences of various employees and managers. The best management practices include repetition of message, promotion of off-the-job safety, participation of senior management, continuous training, and employee involvement.

Standards and Requirements

Contract 48 stands as the fundamental basis for LLNL operations. It provides the legal foundation for all activities. Clause 6.7 of Contract 48 is the foundation of Integrated Safety Management and is consistent with DOE P 450.4 (LLNL 2002db).

Work Smart Standards

Clause 5.5 of Contract 48 contains the language providing for Work Smart Standards, which establish workplace safety controls and are an integral part of Integrated Safety Management. DOE, University of California, and LLNL collaborated in the necessary and sufficient process to tailor Work Smart Standards for LLNL, which replaced existing contractual ES&H requirements. An outside independent team of ES&H experts confirmed the standards to be appropriate and feasible for LLNL in March 1999. On August 5, 1999, the DOE Oakland Operations Manager and LLNL Director gave signature approval for the Work Smart Standard set, which was incorporated into Contract 48 (LLNL 2003k).

Maintenance of Work Smart Standards

These Work Smart Standards can be modified to meet LLNL's changing needs. A formal change control process, using the necessary and sufficient process, provides a mechanism to keep the Work Smart Standards current.

Flow Down of Requirements

LLNL operations are addressed through safety management processes and controls noted in the ES&H Manual. This manual and other institution-level documents include formal processes for applying requirements locally at the facility and activity levels. A key to the flow down process is the formal incorporation of the Work Smart Standards into the ES&H Manual.

Change Control Process

A formal change control board reviews requests for changes to this description and to the currently separate ISMS description for the LLNL Superblock. The Superblock description addresses hazards that require a higher level of formality and specificity than those for most other LLNL operations. There are three members of the change control board, representing NNSA, University of California, and LLNL. These members are appointed by their respective organizations. The change control board Chair is the NNSA representative (LLNL 2003k).

C.3 OCCUPATIONAL HEALTH AND SAFETY

C.3.1 Occupational Radiation Exposures

Ionizing radiation includes alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. The amount of energy deposited in any medium (e.g., tissue) is measured in rads. A dose of one rad means the absorption of 100 ergs per gram of absorbing tissue. The effect of ionizing radiation on humans is measured in rems and is calculated from the absorbed dose multiplied by a quality factor corresponding to each type of radiation. This dose equivalent is applied to the location, i.e., the human organ, of energy absorption. The dose equivalent for the various human organs can be multiplied by a weighting factor for that organ in order to obtain the effective dose equivalent. The weighting factor of an organ or tissue is the proportion of the risk of effects resulting from irradiation of that organ or tissue to the total risk of effects when the whole body is irradiated uniformly. In this way, the dose equivalent to the various irradiated organs (from various sources and internal and external exposure pathways) can be effectively summed in a manner that allows comparison between exposure scenarios.

Employees working in the radioactive materials area are the site personnel most likely to be exposed to radiation either internally or externally. Exposure pathways for internal dose include inhalation and dermal absorption. Internal exposure is typically monitored by bioassays (e.g., urinalysis, whole-body scans, lung counts). Routine bioassays are done on workers who, under typical conditions, are likely to receive a dose from occupational exposures of 0.1 rem or more in a year. Others who would be assayed include occupationally exposed minors, members of the public, and pregnant workers who are likely to receive an internal dose of at least 0.05 rem (or, in the case of pregnant workers, an equivalent dose to the embryo/fetus). Internal exposures are minimized in keeping with the concept of as low as reasonably achievable, which is applied through the use of engineering devices (e.g., high-volume air hoods), administrative controls, and personal protective equipment such as gloves, protective clothing, and respirators. All work areas are sampled periodically, and areas susceptible to internal exposures are monitored continuously.

External exposures are those received from radiation-emitting sources outside the body; e.g., accelerators, radioactive sources, and radioactive equipment. All personnel at LLNL are assigned a whole-body dosimeter that is attached to their security badge. The badge and dosimeter must be worn at all times when onsite. The dosimeter measures the external radiation dose of the badge wearer.

Dosimeters are read monthly for workers who are likely to receive a measurable external radiation dose under normal conditions, or who could receive a radiation dose under off-normal conditions and might not otherwise be aware of it. They are read quarterly for workers who handle radioactive material but are not likely to receive a measurable external radiation dose under normal conditions, or who would otherwise be aware of off-normal conditions that may result in radiation exposure. They are read semi-annually for workers who are not likely to receive a measurable external radiation dose under normal conditions such as office workers.

The total radiation dose for workers is the sum of internal and external exposure. The total radiation dose to all workers during 2002 was 28.0 person-rem. The maximum individual dose to a worker was less than 2 rem. This is within the regulatory standard for radiological workers, those given unescorted access to radiation areas, of 5 rem per year. Table C.3.1–1 gives the distribution of total (internal + external) annual radiation dose for the recent 5-year period of 1998 through 2002.

TABLE C.3.1–1.—*Distribution of Worker Dose for 1998-2002*

Dose Range (rem)	**Number of Workers**				
	1998	**1999**	**2000**	**2001**	**2002**
>2.0	0	0	0	0	0
1.5 – 1.999	0	0	0	0	3
1.000 – 1.499	0	1	1	3	4
0.5 – 0.999	4	6	3	7	10
0.1 – 0.499	8	24	22	26	30
0.01 – 0.099	85	106	112	126	115
<0.01	7,236	8,868	8,855	8,721	8,979
Total (Population) worker dose (person-rem)	**6.9**	**14.9**	**12.7**	**18.4**	**28.0**

Source: LLNL 2003as.

Worker doses from occupational exposure to radiation are projected based on recent experience with continuing operations and projections of specific additional operation impacts on involved workers. The bulk of the dose to involved workers from current operations (approximately 90 percent of total worker dose) is from operations at Building 332. This trend is expected to continue; changes in involved worker dose at LLNL are due chiefly to increased operations in that building. The only exception to this is for increases due to the National Ignition Facility operations. Worker dose from NIF operations is based on operation-specific studies.

Increases in worker dose due to new and expanded operations would be expected for the No Action Alternative, Proposed Action, or Reduced Operation Alternative described in this document. The Reduced Operation Alternative would see an increase of worker population dose to 38 person-rem per year. The increase would be a result of NIF operations. The No Action Alternative worker population dose would be 90 person-rem per year. The increase in the latter value over that of the previous 5 years would be a result of increased operations in Building 332 and in the NIF. The corresponding Proposed Action dose would be 125 person-rem per year. Increases in the latter over the No Action Alternative would chiefly be a result of the Integrated Technology Project operations and increases in the NIF operations. Maximum individual worker dose would remain within the regulatory standard for the No Action Alternative, Proposed Action, and Reduced Operation Alternative.

LLNL has safety procedures and controls in place to minimize the potential of even inadvertent exposures to personnel. During the recent 5-year period of 1998 through 2002, there were two inadvertent exposures to radiation. LLNL reports such incidents in occurrence reports that include a description of the event, an evaluation of the causes, and corrective actions as appropriate. The dose from these inadvertent exposures is included in the historical record of worker dose (see Table C.3.1-1). These are included in the estimates of radiological impacts to workers for the No Action Alternative, Proposed Action, and Reduced Operation Alternative.

In June 2002, a radiological worker in Building 151 was exposed to radiation as a result of handling unsealed radioactive material. The exposure was discovered during routine monthly processing of ring-type finger dosimeters. Reviews of the work's activities lead to the conclusion that the exposure occurred during handling of californium-249. A dose to the hands of two times the allowed annual DOE extremity radiation dose limit (50 rem) was assigned to the employee. Note that this is an extremity dose, rather than an effective dose equivalent. Higher doses are allowed on extremities than other parts of the body that contain blood-forming organs. The worker did not follow established administrative requirements including requesting ES&H Team support, using adequate shielding, and limiting exposure time. A systematic approach to inform the ES&H Team of activities and operations to improve the integration of the ES&H program were implemented (LLNL 2003ba).

In December 2002, a Fissile Material Handler in the Building 332 Metallography Laboratory detected contamination on his hands after removing them from a glovebox. A second fissile material handler was found to have contamination on his gloves and laboratory coat but subsequent surveys showed that he had received no further contamination. The room was shut down to all programmatic operations and equipment decontaminated. The contamination was determined to originate from a pair of tweezers in an unmarked plastic box in the room. The tweezers were identified as legacy items, with the exact origin undetermined. Subsequent surveys of the laboratory turned up three additional unlabeled items that were contaminated. All such items were appropriately dispositioned. The first fissile material handler was determined to have received an effective dose equivalent of 0.72 rem (LLNL 2003aa).

There were no occurrences involving exposure to radioactivity during the 5-year period prior to 2002.

C.3.2 Chemical and Physical Agent Exposures

As described in Appendix A, LLNL operations and research involve the use of a wide variety of chemicals and physical hazards that could result in short and/or long-term exposures. Workers may be exposed to a variety of chemical and physical hazards at LLNL. Typical physical hazards include non-ionizing radiation, such as static magnetic and electric fields, extremely low frequency fields, radio frequency fields, and microwaves; lasers; electrical shock; falling; and noise; and normal construction activities, skin abrasions, and muscle strains. The purpose of this section is to examine typical potential exposures, expected health effects associated with these exposures, and programs that are in place to limit and reduce potential exposures.

Industrial Hygiene

Some workers at LLNL are potentially exposed to chemicals and physical hazards. LLNL is a research and development facility; therefore, ongoing processes with potential exposure to chemicals occur on a daily basis. The small number of workers who may be exposed to toxic chemicals are exposed in small quantities and only sporadically.

The Hazards Control Department evaluates the workplace to ensure that potential exposures are as low as reasonably achievable. LLNL has a program in place to ensure that the workers are protected from potential workplace hazards. This program is documented in the ES&H Manual (LLNL 2000i).

Engineering controls and safety procedures are the foundation of worker safety at LLNL. These include the facility safety plans, basic safety ground rules that must be followed by all personnel present within a building or area, and the operational safety plans, used primarily by experimenters for specific operations. The operational safety plans are more limited in scope and more specific in content than the facility safety plans.

Toxic Chemicals

Results for toxic material samples collected by the Hazards Control Department in 2001 were reviewed. The sampling activities included routine inspections and use of continuous room monitors, stack monitors, and personnel samplers. Summary sample data for 2001 are shown in Table C.3.2–1. There were 1,350 measurements of ambient air concentrations of toxic materials in 2001. In 1,030 of the 1,350 samples, the concentration of the chemical being analyzed was below the analytical limit of detection (LLNL 2002bk, LLNL 2003bf).

TABLE C.3.2–1.—*Personnel Exposure Monitoring Data For Calendar Year 2001*

Number of chemical analyses performed	1,350
Number of chemical analyses below the limit of detection	1,030 (76.3%)
Number of chemical analyses with measurable results	320 (23.7%)
Number of analyses with results above the DOE action level	1 (0.07%)[a]
Number of analyses above the OSHA PEL or ACGIH TLV	0[a]

Source: LLNL 2003bf.
[a] Data corrected for use of personal respiratory protective devices. Uncorrected numbers indicate 32 (2.4%) sample analyses above the OSHA PEL or ACGIH TLV) (LLNL 2003bf).
ACGIH = American Conference of Governmental industrial Hygienists; DOE = U.S. Department of Energy;
OSHA = Occupational Safety and Health Administration; PEL = permissible exposure limit; TLV = threshold limit value.

There were 32 instances where the measured concentration exceeded established exposure limits, either administrative limits, Occupational Safety and Health Administration permissible exposure limits or American Conference of Governmental Industrial Hygienists threshold limit values; however, in all of these cases, personnel were wearing respiratory protection equipment. The threshold limit values are concentrations of airborne substances that represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects. The limit is based on a normal 8-hour workday and a 40-hour workweek. These results indicate the effectiveness of LLNL's program to maintain worker exposures as low as reasonably achievable (LLNL 2003bf).

All workers who handle or work around hazardous materials must be informed of the hazards and be trained in safe handling techniques. Furthermore, in any work area where hazardous substances are present, there must be a written plan for identifying and labeling hazards, maintaining collections of material safety data sheets, providing ongoing training on hazard recognition and control, and notifying workers of their rights to obtain safety information. The plan may also include other requirements such as the use of personal protective equipment, medical surveillance, and emergency planning. These requirements are fulfilled by meeting Integrated Safety Management requirements described in Document 2.1, "Laboratory and ES&H Policies, General Worker Responsibilities, and Integrated Safety Management," Document 10.2, "LLNL Health Hazard Communication Program," Document 14.1, "Chemicals," and Document 14.2, "LLNL Chemical Hygiene Plan for Laboratories," in the ES&H Manual (LLNL 2000i). The Hazards Control Department assists supervisors and employees in maintaining safe work areas by providing information on the hazardous properties of materials, recommending methods for controlling them, and monitoring the work environment (LLNL 2000i).

The Health Services Department provides an opportunity to all LLNL employees who work with hazardous chemicals to receive medical attention whenever an employee develops signs or symptoms associated with a hazardous chemical to which the employee may have been exposed or when medical surveillance is required by Work Smart Standards. In addition, the Health Services Department provides medical attention whenever an event takes place in the work area, such as a spill, leak, explosion, or other occurrence resulting in the likelihood of a hazardous exposure. After the examination and treatment, the Health Services Department provides recommendations for further medical followup, including any work restrictions (LLNL 2000i).

Carcinogens

Potential carcinogens are only used in LLNL operations when it is not possible to use noncarcinogenic material. Any use of carcinogens requires stringent controls to be in place to prevent exposures to workers, the public, and the environment. Examples of activities with the potential for exposure to carcinogenic material are listed below:

- Brazing with cadmium-containing alloys or grinding of cadmium-coated work pieces
- Work that generates or involves contact with soots and tars, including coal gasification; use of mineral oil products that may contain polyaromatic hydrocarbons; work performed in close proximity to diesel engines running indoors; electric arc discharge machining; and discharging of gas propellants in a vacuum
- Handling refractory ceramic fibers
- Welding stainless steels, due to the formation of hexavalent chromium compounds and nickel oxide
- Plating chromium and conducting other operations that disperse hexavalent chromium compounds or irritatingly strong concentrations of sulfuric acid into the air
- Generating hard wood dust including carpentry and cabinetry
- Applying sprays of hexavalent chromium compounds including, but not limited to, primers, paints, and sealants containing barium, calcium, sodium, strontium, or zinc chromate
- Handling inorganic arsenic compounds and arsenic metal, including gallium arsenide, in a manner that can result in exposure to arsenic

- Handling animals in research activities involving carcinogens
- Using or synthesizing carcinogens in chemistry or biochemistry laboratories

When potential or actual carcinogens are used in operations, a responsible individual ensures that all controls specified in the ES&H Manual are in place before starting work. Some limitations and exceptions may be permitted as defined in a governing safety plan, facility safety plan, or operational safety plan.

Responsible individuals in laboratories, with the assistance of the ES&H Team, screen new materials using the LLNL list of controlled carcinogens for laboratories. For nonlaboratories, information on material safety data sheets, product label, or vendor's literature is used to determine if a potential carcinogen is present as well as the LLNL list of controlled carcinogens for nonlaboratories. The Occupational Safety and Health Administration requires that potential carcinogens in concentrations greater than 0.1 percent be listed on the material safety data sheets. If these sheets indicate that the material is a carcinogen, then it is screened using the LLNL list of controlled carcinogens for nonlaboratories.

The responsible individual, with the assistance of the ES&H Team, analyzes operations involving carcinogens to determine the hazard(s) involved and the applicable controls. The formality of the analysis depends on the type of carcinogen involved—human or other—and the complexity of the operation. Some operations may require a detailed analysis to determine if additional controls are necessary. An analysis is not required for carcinogens kept in storage if the reactive and physical hazards (e.g., flammability) and storage concerns (e.g., leaks due to corrosion of containers) are adequately addressed.

Work procedures are required for certain activities involving carcinogens. Work with carcinogens beyond the scale and controls specified on the governing Hazard Assessment and Control form or in the safety plan are reviewed by the ES&H Team industrial hygienist and documented in a revised hazard assessment. Hazard Assessment and Control forms are described in Document 11.1, "Personal Protective Equipment," in the ES&H Manual (LLNL 2000i).

An evaluation of the waste stream would be conducted prior to the start of operations to determine if the waste to be generated needs to be managed as hazardous. The State of California regulates 16 carcinogens as hazardous wastes if any are present in excess of 0.001 percent by weight (10 parts per million). In addition, other substances that have "...been shown through experience or testing to pose a hazard to human health or environment because of its carcinogenicity" would be managed as hazardous waste. The ES&H Team environmental analyst would provide assistance in this determination. If the waste is determined to be hazardous, it would be managed and handled in accordance with Document 36.1, "Waste Management Requirements," in the ES&H Manual.

Employees working with carcinogenic compounds receive training in accordance with Document 14.2, "LLNL Chemical Hygiene Plan for Laboratories," and Document 10.2, "LLNL Health Hazard Communication Program," in the ES&H Manual (LLNL 2000i).

Non-ionizing Radiation

The ES&H Manual provides guidance to ensure that non-ionizing radiation sources are identified and posted, users are properly trained to work with and around these sources, and measurements are taken to evaluate worker exposures. Controls to mitigate hazards would be implemented when surveys indicate that exposures can exceed acceptable limits. Examples of these potential hazards include:

- Static magnetic and electric fields
- Extremely low-frequency fields with frequencies below 300 hertz, including powerline fields at 60 hertz
- Radio-frequency fields and radiation with frequencies below 300 megahertz
- Microwave radiation with frequencies between 300 megahertz and 300 gigahertz

Engineered controls (e.g., shielding and isolation) are used to restrict exposure whenever practical. Signs complying with good industrial practice, as specified in Document 12.1, "Access Control, Safety Signs, Safety Interlocks, and Alarm Systems," in the ES&H Manual, are posted conspicuously inside and at all entrances to designated potential hazards areas.

Anyone who may reasonably expect to be exposed to fields or radiation emitted by the equipment producing the types of hazards listed above is required to take Course HS4370, "Fields and Waves." This web-based course covers the health effects of radio frequency/microwave radiation and fields and static magnetic fields (LLNL 2000i).

Lasers

LLNL uses many types of lasers, from small lasers used in a laboratory or the field, to large lasers, such as the NIF. Work standards for the safe operation of lasers and laser systems at LLNL follow the recommendations of ANSI Z136.1-2000, "American National Standard for Safe Use of Lasers" (ANSI 2000) and ANSI Z136.2-1997 "American National Standard for Safe Use of Fiber Optic Communication Systems Utilizing Laser Diode and LED Sources (ANSI 1997)." Examples of lasers and laser systems that are used at LLNL may include:

- Commercially available lasers used as part of an experiment or laser development
- LLNL-designed or LLNL-built lasers or laser systems
- Applications of any laser or laser system that are determined to be hazardous by the LLNL Laser Safety Officer, Hazards Control Department, or directorate management following an inspection, evaluation, or review, based on an intended use or application at LLNL
- Commercially available lasers that have been modified, assembled, or incorporated into a device built by LLNL

Using any laser involves exposure to varying degrees of hazards. Most lasers at LLNL can injure the eyes of those who look directly into the beam or its specular, mirror-like reflection. In addition, diffuse reflections created by some high-power laser beams can cause permanent eye damage. High-power laser beams can also burn exposed skin, ignite flammable materials, and heat materials so that they release hazardous fumes, gases, debris, or ionizing and non-ionizing radiation.

The most common hazard when working with lasers is eye injury. To prevent such an injury, workers must avoid looking directly into the laser beam or its specular reflections. This rule must be followed regardless of the protective eyewear worn or the type of hazard classification of laser unless specifically authorized in an operational safety plan or integrated work sheets/safety plan.

The classification of lasers and laser systems is based on the capability to cause injury. Class 1 and Class 2 are considered low-hazard lasers. Class 3a lasers are considered medium-hazard lasers. Class 3b and 4 lasers are considered high-hazard lasers and require more stringent controls.

Equipment and optical apparatus required for producing and controlling laser energy introduce other hazards, including high voltage, high pressure, cryogenics, noise, additional radiation, flammable materials, laser dyes and solvents, and toxic fluids.

Prior to the initial use of a laser or laser system, the responsible individual conducts pre-work planning. Steps to be conducted include:

- Review the proposed project.
- Complete a hazard analysis.
- Select the necessary controls to minimize exposure.
- Identify the work procedures to be followed.
- Identify the personnel who will be conducting the operation and the materials and hardware to be used.

The level of detail for each step depends on the proposed activity's complexity and degree of risk. Because many controls for lasers are case-dependent, early involvement of the area ES&H Team is essential. The original project decisions may have to be modified after further analysis. These pre-job reviews are typically performed using the integration work sheet process. Pre-work planning, using the integration work sheet, encompasses the specific hazards of building up a system, including initial laser and optical alignments, connections to power, pressurized systems, etc. Appendix B of Document 20.8, "Lasers," and Document 3.4, "Preparation of Work Procedures," in the ES&H Manual (LLNL 2000i) provides guidance for considerations in writing a beam-alignment procedure.

Many hazards other than laser radiation can be found in the laser area. The responsible individual must adequately control the hazards to prevent injury while working with lasers. Some of these nonlaser hazards are discussed in the following sections.

Dyes and Solutions

Dye lasers normally use a lasing medium that comprises a complex, fluorescent, organic dye dissolved in an organic solvent. Animal experimentation has shown these dyes to vary greatly in toxicity and carcinogenicity, and several have been found to be mutagens. In many instances, the solvent in which the dye is dissolved plays a major role in the solution's hazards. Most suitable dye solvents are flammable and toxic if inhaled, ingested, or absorbed through the skin.

To protect workers, the public and the environment, dye lasers are sealed systems that are only opened for maintenance purposes; e.g., to replace spent dye. The handling of the dyes is performed by trained personnel working under formal procedures that include the use of appropriate protective equipment.

Electrical Equipment and Systems

The responsible individual ensures that the installation, operation, and maintenance of electrical equipment and systems conform to the standards in Document 16.1, "Electrical Safety," in the ES&H Manual. Laser tables are always electrically connected to the building ground. Because interlock switches are energized from a different source than the equipment they control, an interlock switch is energized even if the laser equipment is not energized.

Gases Used in Lasers

When toxic gases are used as a lasing medium, exhaust ventilation is needed to remove gases that could escape into occupied areas. Conditions warranting ventilation at system connections could be filling, purging, or recharging. Document 14.3, "Toxic, Corrosive, or Reactive Gases," and Document 12.2, "Ventilation," of the ES&H Manual (LLNL 2000i) address applicable requirements for local exhaust ventilation.

Hazardous Materials

Adequate controls are used to prevent laser beams and strong reflections from impinging on combustible materials, explosives, highly flammable liquids or gases, or substances that decompose into highly toxic products under elevated temperatures.

Non-ionizing Radiation

Electromagnetic fields and radiation may be generated by laser systems or support equipment. Objects, when struck and vaporized by laser beams, can emit noncoherent optical radiation.

If indicated by the pre-work planning review, integrated worksheets, or operational or facility safety plans may be required for laser operations. Operational safety plans may include or reference plan-view drawings that may show the locations of the safety interlock systems. The drawings show the location of interlock sensors, such as door switches or floormat sensors, laser shutters, or power supplies controlled by the interlock system, status displays, panic buttons, and interlock system controllers.

All operators of lasers or laser systems are required to read the safety instructions provided by the equipment manufacturer. In addition, laser experimenters who operate Class 3b, or 4 lasers, or Class 1 laser systems containing embedded Class 3b or 4 lasers, except for commercial instruments that are only serviced by vendor representatives, are required to:

- Receive a thorough review of the laser equipment to be used from the responsible individual. The payroll or program management organizations may require further training.
- Successfully complete Course HS5200-CBT.
- Read Document 20.8, "Lasers," and any relevant operational safety plans and work procedures.

Noise

Exposure to excessive levels of noise can result in permanent hearing loss, acuity, development of tinnitus (i.e., ringing of the ears), a possible increase in blood pressure, and stress-related problems. Noise may also cause annoyance or difficulty in communicating or working effectively and safely. Requirements for noise reduction, monitoring, and personnel protection are contained in Document 18.6, "Hearing Conservation." LLNL adopted the American Conference of Governmental Industrial Hygienist threshold limit values of 85 A-weighted decibels (dB[A]) for noise instead on the Occupational Safety and Health Administration permissible exposure limit of 90 dB(A), which is more protective. The remaining parts of the Occupational Safety and Health Administration regulation 29 CFR §1910.95 were adopted. LLNL's Hearing Conservation Program involves:

- Identification of exposed personnel (monitoring)
- Implementation of noise-reducing engineered and administrative controls
- Audiometric testing (baseline and annual)
- Training
- Use of hearing protectors (plugs, ear muffs)

LLNL uses both engineering and administrative controls to limit noise exposure. The best way to limit exposure is to alter the noise-producing equipment or change the environment to reduce noise levels. Examples include replacing old, noisy equipment; increasing sound dampening around noisy equipment; and improving muffler design. Engineered controls are formally considered before other types of controls are implemented.

Administrative controls for limiting noise exposure include:

- Performing noise measurements to identify areas or specific operations that produce excessive noise or to evaluate a worker's exposure to noise throughout an 8-hour day. The results of the measurements are used to determine which, if any, controls are appropriate to reduce worker exposure to noise.

- Altering work schedules. An employee scheduled to work on several pieces of noisy equipment should perform the noisy tasks over several days so that the average exposure each day does not exceed the permissible limit.

- Posting caution labels or signs on equipment or in areas where it has been determined that noise levels may exceed 85 dB(A). These signs notify the worker of a potential noise hazard and specify the conditions under which hearing protectors are recommended or required. Caution labels and signs are particularly important where workers' duties require them to move among different locations or to use a variety of tools. The purpose and meaning of the signs are included in the training aspect of LLNL's Hearing Conservation Program.

- Conducting medical surveillance examinations to monitor the hearing acuity of workers exposed to noise levels exceeding the established limits. Medical surveillance is not routinely required for workers who are exposed to nuisance noise. The Health Services Department generally performs medical surveillance only for LLNL workers. Non-LLNL employees receive medical surveillance through their employer.

LLNL workers exposed to noise above the adopted criteria are required to meet all the requirements of 29 CFR §1910.95, which include annual training on the health effects of noise exposure and instructions on how to fit and wear hearing protectors and a baseline exam and annual followup audiometric testing.

San Joaquin Valley Fever

Anyone who works at or visits Site 300 may be exposed to an organism that causes Valley Fever (coccidioidomycosis), a respiratory infection common throughout the San Joaquin Valley. All LLNL employees assigned to Site 300 are offered a skin test to assess their susceptibility to the organism. The test, subject to availability of the antigen, is currently unavailable and may remain unavailable beyond 2003. San Joaquin Valley Fever is endemic throughout the San Joaquin Valley and other areas of California, Arizona, and New Mexico. Certain groups (i.e., African Americans, Asians, Filipinos, Hispanics, immuno-suppressed persons, pregnant women, and unborn children) are at risk for developing the disseminated form of San Joaquin Valley Fever; i.e., the organism may spread beyond the lungs if an individual at risk becomes ill with San Joaquin Valley Fever. An estimated 50,000 to 100,000 persons develop symptoms of Valley Fever each year in the U.S., with 35,000 new infections per year in California alone. The incubation period is 10 to 30 days and the incidence is about 1 out of 100,000 people. Less than 10 percent of infections progress to more severe illnesses, and in rare cases the fungus moves outside the lungs to the muscles, bones, or skin. At its worst, this disease can cause a form of meningitis—leading to between 50 and 100 deaths per year (Valley Fever 2003a, 2003b).

The risks associated with this endemic hazard are discussed in the required Site 300 training. The Health Services Department is available to provide counseling for individuals. Subcontractors and other non-LLNL organizations providing workers at Site 300 are notified of potential San Joaquin Valley Fever hazards in the workplace. Employees, consultants, or other individuals who visit Site 300 briefly are not informed on an individual basis of the possibility of exposure to San Joaquin Valley Fever. However, the safety training required for unescorted Site 300 entrance discusses the hazards of San Joaquin Valley Fever. In addition, signs stating the risks of exposure are placed at or near all entrances to Site 300, and information is available at the site's medical facility (LLNL 2000i).

Biological Materials

Biological operations often involve work with hazardous materials. Some individuals may have increased susceptibility to biohazards due to preexisting diseases, use of medications, compromised immunity, pregnancy, or breast-feeding. These factors are addressed as part of the hazard assessment described in Document 2.2, "Managing ES&H for LLNL Work," in the ES&H Manual (LLNL 2000i).

Guidance documents, such as those listed below, are often used to determine the level of exposure to biological hazards.

- Center for Disease/National Institute of Health, Classification of Human Etiologic Agents on the Basis of Hazard http://www4.od.nih.gov/oba/rac/quidelines (CDC/NIH n.d.)
- Center for Disease/National Institute of Health, BioSafety in Microbiological and Biomedical Laboratories (CDC/NIH 1993)
- National Cancer Institute, BioSafety Manual for Research Involving Oncogenic Viruses (NIH 1976)

LLNL activities are restricted to BioSafety levels (BSL)-1 and -2, as defined by Center for Disease/National Institute of Health. Activities that require BSL-3 precautions are permitted only in a BSL-3 facility.

At LLNL, biological operations include the following:

Healthcare and Emergency Response

The biohazards involving human tissue and human body fluids and encountered in caring for ill or injured people have been determined by the Occupational Safety and Health Administration to have the potential for contaminating workers with bloodborne pathogens, including but not limited to, the Hepatitis B virus, Hepatitis C virus, and the human immunodeficiency virus. Requirements and guidance for dealing with bloodborne pathogens can be found in Document 13.2, "Exposure Control Plan: Working Safely with Blood and Bloodborne Pathogens," and Document 36.1, "Waste Management Requirements," in the ES&H Manual (LLNL 2000i).

Laboratory Research Operations

Research operations may involve work with specific microbial (i.e., risk group) agents, human tissue or body fluids, human or primate cell culture lines, or animals. Work with human or primate cell culture lines poses a hazard because the presence of latent viruses may exist incidentally or deliberately from experimental infections. Primary and permanent human or animal cell lines from nonlymphoid cell lines should be regarded as carrying low-hazard viruses unless known to be infected with a more hazardous agent. All primate cell lines derived from lymphoid cells, primate tumor tissue cell lines, primate cell lines exposed to or transformed by a primate oncogenic virus, primate cell lines contaminated with mycoplasma, and permanent human lymphocyte cell cultures are assumed to harbor moderate or higher hazard agents.

Plant Engineering Maintenance and Grounds-keeping Activities

Sewage workers, plumbers, electricians, and other tradespersons, as well as janitors and gardeners, may come into contact with chemicals, human body fluids, or other potentially contaminated materials. Hazards to plant engineering maintenance and grounds workers include exposure to biological or chemical agents that normally may be present in the environment such as wild animals or fungal spores. Hazards may be contained in animal vectors, tissues, fluids, carcasses, or droppings.

Environmental Surveillance

Livermore Site and Site 300 drinking water may have radiological, physical, chemical, and biological contamination, such as low or high pH, increased residual chlorine level, bacteria, and fecal coliforms (e.g., *E. coli*). The sewer treatment process at Site 300 has the potential for introducing fecal coliform contamination from the sewer pond to the groundwater.

Facility Restoration

When replacing water-damaged materials (e.g., sheetrock, ceiling tiles, rugs, and siding), workers may be exposed to toxic fungal agents or their metabolites. Unoccupied or unused buildings may contain rodents or birds and their droppings, as well as poisonous snakes, insects, or spiders. The process of decontaminating facilities that have been used for biological research or other work involving animals or human biological fluids may expose workers to biological agents or the decontaminating agent.

Waste Disposal Operations

Workers who package and handle waste containing biological materials may be exposed to biohazards such as microbial agents and human or animal fluids or tissues if such materials are not properly handled and packaged.

Shipping and Transportation

Shipping or transport of biological materials, including microbial agents, human or animal fluids or tissues, animals, or biological waste, may result in worker exposure because of damaged shipping containers, improper packaging, or mishandling.

Animal Handling

Research with animals poses hazards to the animals and the handler. Hazards include allergic responses and illnesses from direct or indirect exposure to infectious agents and infectious test agents found in animal tissues, fluids, carcasses, or droppings. Exposure to such hazards may occur through dust inhalation, bites, scratches, handling cages, contact with waste materials, or direct contact with animals.

Biological Operations

Through implementation of ISMS processes, LLNL attempts to prevent or mitigate the hazard(s) associated with biological operations and work involving biohazardous agents and materials. Three methods of mitigation are used as discussed in the text box below.

Engineered controls—These include facility design requirements, such as high-efficiency particulate air filters, interlocks, and negative airflow units, and safety equipment, which include mechanical aids such as tongs and tweezers, dead air boxes, sharps containers, laboratory-type fume hoods, biological safety cabinets, also referred to as biosafety cabinets, shielding, safety centrifuge cups, and special shipping containers for transporting biological materials and animals.

Administrative controls—These include the hazard review process and the use of procedures and operational controls for the performance of work.

Personal protective equipment—Equipment includes gloves, coats, gowns, shoe covers, safety shoes, boots, respirators, face shields, and safety glasses or goggles. Personal protective equipment is only used as supplemental protection if there is still a residual risk of exposure after engineered and administrative controls are implemented.

Multiple safety standards have been established to ensure that proper facilities and procedures are employed while working with biological materials with varying degrees of potential hazard. All work on biological materials is conducted in appropriate facilities, such as the Biomedical Sciences Buildings and the Health Services Clinic, according to the potential hazard.

BSL-1 is suitable for work involving well-characterized agents not known to cause disease in healthy adult humans, and of minimal potential hazard to laboratory personnel and the environment. The laboratory is not necessarily separated from the general traffic patterns in the building. Work is typically conducted on open bench tops using standard microbiological practices. Special containment equipment or facility design is not required nor generally used. Laboratory personnel have specific training in the procedures conducted in the laboratory and are supervised by a scientist with general training in microbiology or a related science (CDC/NIH 2003).

BSL-2 is similar to BSL-1 and is suitable for work involving agents of moderate potential hazard to personnel and the environment. It differs in that laboratory personnel have specific training in handling pathogenic agents and are directed by competent scientists, access to the laboratory is limited when work is being conducted, extreme precautions are taken with contaminated sharp items, and certain procedures in which infectious aerosols or splashes may be created are conducted in biological safety cabinets or other physical containment equipment (CDC/NIH 2003).

BSL-3 is applicable to clinical, diagnostic, teaching, research, or production facilities in which work is done with indigenous or exotic agents which may cause a serious or potentially lethal disease as a result of exposure by the inhalation route. Laboratory personnel have specific training in handling pathogenic and potentially lethal agents, and are supervised by competent scientists experienced in working with these agents. All procedures involving the manipulation of infectious materials are conducted within biological safety cabinets or other physical containment devices, or by personnel wearing appropriate personal protective clothing and equipment. LLNL has special engineering and design features. It is recognized, however, that many existing facilities may not have all the facility safeguards recommended for BSL-3, such as access zone, sealed penetrations, and directional airflow, etc. In these circumstances, acceptable safety may be achieved for routine or repetitive operations (e.g., diagnostic procedures involving the propagation of an agent for identification, typing, and susceptibility testing) in BSL-2 facilities. However, the recommended standard microbiological practices, special practices, and safety equipment for BSL-3 must be rigorously followed. The decision to implement this modification of BSL-3 recommendations should be made only by the laboratory director (CDC/NIH 2003).

Additional guidelines have been developed for handling laboratory animals and research activities involving the use of clinical specimens, such as human blood. Employees working with potentially pathogenic micro-organisms, human cells, or other samples that may contain infectious agents, have their blood serum sampled by Health Services as a baseline for future assay in the event of accidental exposure (LLNL 2000i).

Occupational Safety

Occupational safety was evaluated through a review of occupational injury and lost workday case rate data from 1996 through 2001. Occupational illness/injury case rates are recorded as the number of cases per 200,000 hours, or approximately 100 person-years worked. In comparison to other DOE research contractors, LLNL ranks 19 of 27 for the rates of lost or restricted workdays (DOE 2002l).

Six-Year Trend Data (1996–2001)

Table C.3.2–2 lists recordable and lost/restricted workday cases and case rates for the years 1996 through 2001.

TABLE C.3.2–2.—*Summary of Occupational Safety and Health Administration Log Injury/Illness Data*

Calendar Year	Recordable Cases	L/RWD Cases	Recordable Case Rates	L/RWD Case Rates
1996	509	204	6.9	2.8
1997	530	198	7.3	2.8
1998	452	144	6.1	1.9
1999	349	98	4.7	1.3
2000	360	121	4.9	1.7
2001	309	107	4.3	1.5
2002	234	73	3.0	0.9

L/RWD = lost/restricted workday.

The following trends for occupational injury were identified for LLNL. The total recordable case rates per 200,000 hours worked ranged from 7.3 in 1997 to 3.0 in 2002 compared to DOE values of 3.5 for 1996 to 2.2 for 2002 (DOE 2002f, LLNL 2002ck, LLNL 2003u). The lost/restricted case rates per 200,000 hours worked ranged from 2.8 in 1996 and 1997 to 0.9 in 2002 compared to DOE values of 1.7 for 1996 to 0.9 for 2001 (DOE 2002f, LLNL 2003u).

The total number of recordable injuries that require medical attention beyond first aid and are reported to DOE was reduced from a high of 530 in 1997 to 234 in 2002. Of these injuries, overexertion (e.g., muscle strains, back strains) contributed 40 percent, wounds contributed 20 percent, cumulative trauma (e.g., carpal tunnel syndrome) contributed 34 percent, skeletal injuries contributed 3 percent, and injuries listed as other contributed 2 percent (LLNL 2003aw, OSHA 2001).

Specific Accident Information from 1996 through 2001

In addition to occupational exposures, unusual occurrences may result in worker exposures to toxic substances and other physical hazards such as electrical shock. When certain types of incidental accidents occur, LLNL is required to document them in environmental incident and/or unusual occurrence reports, and transmit them to DOE and other state and Federal agencies when necessary. A summary of reportable occurrences at LLNL in the 6 years from 1996 through 2001, as reported in occurrence and incident reports that resulted in workers being taken to the hospital or to the Health Services Department, is listed below:

- In March 1996, an employee crossing West Inner Loop Road near Building 271 was struck by a pickup truck driven by a subcontractor. The employee was thrown approximately 50 feet and landed beside the roadway. The employee suffered serious injuries and was taken to Eden Hospital Trauma Center by California Shock Trauma Air Rescue (CALSTAR).

- In June 1996, a subcontractor electrician installing electrical components on the outside wall of Building 121 caused an electric arc and flash by accidentally contacting the energized bus. The arc damaged a section of the electric panel and the flash caused a first-degree burn on the left forearm of one of the electricians. The electrician was taken to a local hospital, observed for 2 hours and released.

- In August 1996, a participating guest received an electrical shock while working with a photo-multiplier tube. The shock occurred when he touched the tube's magnetic shielding.

The guest was taken to Health Services and released a half-hour later without restrictions. He suffered a minor burn to the right palm.

- In September 1996, an experimenter was disassembling some equipment located in a room that had been constructed within the highbay of Building 241 for his high pressure experiment. The employee had apparently removed the bolts that were holding up two steel plates that were 48 inches wide by 72 inches tall by 1/2 inch deep that stood vertically on the floor. The steel sheets, weighing approximately 900 pounds, fell over, knocking the employee down and pinning him. He was transported by LLNL's Fire Department to the hospital, where he underwent surgery to reconstruct his shattered right ankle, set his broken left leg, and tend to his other injuries.

- In September 1996, a Human Resources employee was returning to LLNL from an offsite Bay Area Apprenticeship Meeting in Oakland, California, when they were involved in a single-car automobile accident. The employee was transported by ambulance to Eden Hospital in Castro Valley, California, for observation.

- In November 1996, a safeguards and security employee in the locks and keys group was exposed to a laser beam that was being reflected off a target. The laser, a Spectra Physics Model 127 HeNe, emits 30 megawatts, and the estimated reflection was 8 percent of the total power. The employee was taken to Health Services where he indicated he had some "after image" which was fading. The employee was sent to an ophthalmologist for an eye examination where it was determined that no permanent eye damage had occurred.

- In August 1996, a sheet metal worker fell through the fiberglass ceiling of Room 1203 in Building 231, approximately 7 feet and 6 inches to the cement floor, when the wooden beam he was walking on moved. The employee was taken to Valley Care in Pleasanton, California, where he was x-rayed and CAT-scanned. No internal injuries or broken bones were found and the employee returned to work 2 days later.

- In May 1996, an employee in the Plating Shop was pouring Ebonol C, known as sodium chlorite/sodium hydroxide, powder into a de-ionized water bath when the bath erupted violently, spewing hot caustic solution into the air, burning himself and another employee working 10 feet away. Both employees were treated at the medical facility and returned to work.

- In March 1997, an employee was meeting a vendor at the LLNL south cafeteria. As she was walking across the parking lot to enter the building, she caught her toe on the raised cement edge of a planter next to the building. She fell and landed on her left arm. The employee was diagnosed with a torn rotator cuff in her left shoulder. Surgery was required.

- In April 1997, a contract (non-LLNL) employee performing routine construction work fell approximately 6 feet from a 10-foot ladder, landing on his feet, falling backwards, and coming to rest on his back. The worker was conscious and alert but complained of pain. He was airlifted to Eden Hospital in Castro Valley. The worker was found to have a fracture of the "L-4" vertebra and was hospitalized.

- In April 1997, a 1995 General Service Area-leased Ford pick-up truck was being backed up to a turn-around area on a fire road at Site 300, several hundred yards west of the small arms firing range in the southwestern portion of the site. The driver's side rear wheel came close to the shoulder of the fire trail. At that time, the shoulder and supporting soil gave way, dropping the right rear of the vehicle off the trail to the hillside slope. The vehicle continued to slide, then slowly rolled 1-1/2 times, landing on its cab 15 to 25 feet below the trail. The driver was taken to Tracy (Sutter) Memorial Hospital, x-rayed, and released.

- In May 1997, in Room 338 of Building 391, an electrician was investigating an interruption to a capacitor cycling operation. The electrician discovered a charged capacitor while ground hooking the system. A resulting arc noise occurred, causing a companion worker to experience ear pain and discomfort. Health Services referred the affected individual to an ear, nose, and throat specialist where it was determined that he had ruptured an eardrum.

- In July 1997, an employee was in the area northwest of Building 190 when he tripped or lost his balance near a small drainage culvert and fractured his ankle/leg. The injured employee was transported to a nearby offsite hospital. Surgery was required to repair the fractured ankle/leg.

- In September 1997, a government van driven by a security escort and an Advancement and Independence for the Disabled Employment employee, who was riding a LLNL bicycle, were involved in a collision onsite. The bicycle rider was transported by helicopter to Eden Hospital for treatment and observation.

- In June 1998, a contractor steel worker received lacerations to his head when his hard hat was pinched between a steel beam and the outrigger of a mobile crane when a steel truss section was accidentally lowered onto that beam. The injured worker was given first aid at the scene by his foreman, by LLNL emergency response personnel, and subsequently transported to Eden Trauma Center, where he was examined, treated, and released.

- In July 1998, a Human Resources employee on a bicycle made a sudden stop at the intersection of Inner Loop Road. In doing so, the employee placed both feet on the ground, resulting in the twisting of her ankle while slipping and falling from the bike. The employee was transported to Valley Care Hospital by the LLNL Fire Department. X-rays were taken, reflecting a compound fracture in her right ankle.

- In August 1998, a forklift driver drifted off the paved road onto the shoulder. When he hit a dip in the road, the forklift became uncontrollable and he lost control of the vehicle. The driver was not wearing a seatbelt and so was thrown from the vehicle and injured when his head hit an overhead guard. The employee was transported to Eden Hospital by ambulance. He was admitted overnight for observation and released the next morning.

- In August 1998, a protective force officer lost control of his vehicle, resulting in a single-vehicle roll-over accident with injury. The officer was transported to John Muir Hospital, Walnut Creek, California, via CALSTAR.

- In August 1998, an employee fell from his personal bicycle. He had exited a CAIN security booth on bike and lost his balance as he was mounting it, falling and fracturing his hip. The individual was transported to Valley Care Hospital, was admitted, and underwent surgery.

- In December 1998, a scientist was working alone in a Building 194 laser laboratory, Room 1117B. He was struck by a stray laser beam that came from a polarizer deflecting a beam from the plane of the table. The scientist received an injury to his right eye. He was taken to LLNL Health Services, where he was examined and directed to Valley Care Hospital in Pleasanton, where he was referred to an ophthalmologist. Further evaluation by a retinal specialist revealed broken blood vessels in the eye. The physicians concluded there would not be permanent eye damage.

- In May 1999, a mechanical technician received a momentary electrical shock when he contacted an energized exposed electrical conductor. The employee was taken to onsite Health Services for evaluation and returned to work.

- In August 1999, an employee reported a laser eye injury that he had in fact sustained in October 1998. The affected employee received a medical examination and consultation with medical personnel.

- In December 1999, five workers suffered headaches after being exposed to fumes from an adhesive used to glue sheets of foam to the inside of wood shipping crates. All involved individuals were sent to Health Services for evaluation and subsequently returned to work without restriction.

- In January 2000, a construction worker at the NIF site was injured when rebar that he was bending suddenly broke, causing him to lose his balance and fall. He was taken by ambulance to the hospital emergency room and after medical treatment was released without restriction.

- In January 2000, a construction worker in Switchyard 2 of the NIF site was injured when a 42-inch-diameter heating, ventilation, and air conditioning duct swung down and hit him. The worker was knocked down and complained of back pain. He was air lifted by helicopter to a local hospital where he was admitted.

- In March 2000, a hazardous waste technician was processing laboratory waste from the Biology and Biotechnology Research Program at the Hazardous Waste Management yard, when one of at least two hypodermic needles penetrated the bag and stuck the technician in his arm. The technician was transported to Health Services where he was treated and released.

- In April 2000, plant engineering laborers in the Building 431 high bay were moving a portable tent covered with heavy plastic sheeting used for enclosing laser experiments. As they were moving the frame to relocate the portable tent, a piece of plywood, measuring 4 feet wide by 6 feet long by 3/4 inches thick, fell approximately 12 feet, striking a laborer in the upper back and neck area. The employee was sent to LLNL Health Services, and was then sent to an outside medical facility for x-rays. It was determined that he had sustained a fractured vertebra.

- In May 2000, a government vehicle and private vehicle collided at an intersection near the LLNL East Gate. The LLNL Fire Department responded to the scene and transported the driver of the government vehicle to the LLNL Health Services Department. The individual was then transported to the Valley Care Medical Facility.

- In October 2000, an employee traveling on a bicycle to Building 177 fell from his bicycle, landing on his tailbone, bumping his head, and scraping an elbow. The victim was transported to Valley Care Hospital where he was held for observation, diagnosed with a fractured L-1 vertebra, and released the same day.

- In November 2000, a security department protective service officer was attempting the 40-yard dash from a prone position, as required by the DOE physical fitness standard. The officer completed the required dash and was approximately 15 feet past the finish line when he fell face first onto the pavement. The LLNL Fire Department responded and assisted the officer who was transported to Eden Hospital in Castro Valley via CALSTAR.

- In April 2001, there was an unanticipated release of a gas cylinder in Building 511 containing hydrogen fluoride resulting from reaction of rhenium hexafluoride with moisture in the air. This release resulted in the potential exposure of five workers to hydrogen fluoride gas. The workers were transported to LLNL Health Services because of possible chemical inhalation, and then transported to Valley Care Hospital in Pleasanton. They were released with no ill effects noted (DOE 2003c).

C.3.3 Radiation Exposure Risk

High-level exposure to radiation is referred to as 'acute' exposure. The effects of such exposure usually appear quickly and can range from nausea (exposure of at least 50 rem to the whole body) to death within hours or days (exposure of at least 2,000 rem to the whole body) (EPA 2003f). Radiation exposure experienced by individuals at LLNL (<5 rem for workers, <0.0001 rem for the maximally exposed member of the public) can be characterized as low-level radiation. The most significant potential health effect from low-level radiation is the induction of latent cancer fatalities. Such effects are characterized by their stochastic nature. That is, exposure to low-level radiation results in a possibility of the formation of a latent cancer; as the dose increases the probability of the effect increases, although the severity does not. The effects are referred to as "latent" because the cancer may take many years to develop. Low-level radiation may also cause nonfatal cancers and genetic disorders.

The Interagency Steering Committee on Radiation Standards (Lawrence 2002) recommended a risk estimator of 0.0006 excess fatal cancers per person-rem of dose in order to assess health effects to the public and to workers. The health risk estimators for nonfatal cancers and genetic disorders is one-third that of a cancer fatality.

The radiation exposure risk estimators are denoted as excess because they result in fatal cancers above the naturally occurring annual rate, which is 171.4 per 100,000 population nationally and 161.7 per 100,000 population for California (Ries et al. 2002). Thus, approximately 11,000 fatal cancer deaths per year would be expected to naturally occur in the approximately 7 million people surrounding LLNL. The doses to which they are applied is the effective dose equivalent, which weights the impacts on particular organs so that the dose from radionuclides that affect different organs can be compared on a similar (effect on whole body) risk basis. All doses in this document are effective dose equivalent unless otherwise noted.

The risk of fatal cancer to an individual is determined by multiplying the appropriate risk estimator by the total dose to that individual. For example, the risk of a fatal cancer to the offsite maximally exposed individual (MEI) at the Livermore Site for the No Action Alternative is 1.8×10^{-7} per year of exposure (0.0006 fatal cancers/person-rem × 0.299 millirem per year × 10^{-3} rem per millirem). The number of excess fatal cancers that will be experienced by a population is determined by multiplying the same risk estimator by the total dose to that population. For example, the calculated number of excess fatal cancers to the worker population for the No Action Alternative would be 0.054 per year of operation (0.0006 fatal cancers/per person-rem × 90 person-rem per year). Since the calculated number of excess fatal cancers is much less than one, it is unlikely that any such cancers will be seen in the worker population from one year of operation. There is the possibility of an excess fatal cancer to a worker sometime during that worker's lifetime as a result of operation over an extended period (i.e., many years). A summary of doses and corresponding risks for individuals and populations is presented in Table C.3.3–1.

TABLE C.3.3–1.—*Summary of Doses and Corresponding Risks*

	No Action Alternative		**Proposed Action**		**Reduced Operation Alternative**	
Individuals	**Dose (mrem/yr)**	**Risk of Cancer Fatality**	**Dose (mrem/yr)**	**Risk of Cancer Fatality**	**Dose (mrem/yr)**	**Risk of Cancer Fatality**
Livermore Site MEI	0.30	1.8×10^{-7}	0.33	2.0×10^{-7}	0.22	1.3×10^{-7}
Site 300 MEI	0.055	3.3×10^{-8}	0.055	3.3×10^{-8}	0.054	3.3×10^{-8}
LLNL Involved worker	< 2,000	1.2×10^{-3}	< 2,000	1.2×10^{-3}	< 2,000	1.2×10^{-3}
Populations	**Dose (person-rem/yr)**	**Number of Cancer Fatalities**	**Dose (person-rem/yr)**	**Number of Cancer Fatalities**	**Dose (person-rem/yr)**	**Number of Cancer Fatalities**
Livermore Site offsite	1.8	0 (1.1×10^{-3})	1.8	0 (1.1×10^{-3})	1.8	0 (1.1×10^{-3})
Site 300 offsite	9.8	0 (5.9×10^{-3})	9.8	0 (5.9×10^{-3})	9.8	0 (5.9×10^{-3})
LLNL Involved worker	90	0 (0.054)	125	0 (0.075)	38	0 (.023)
Noninvolved worker	0.14	0 (8.6×10^{-5})	0.16	0 (9.3×10^{-5})	0.13	0 (7.9×10^{-5})

Note: Number of cancer fatalities calculated in parentheses; a value much less than 1, e.g., 5.9×10^{-3} implies no cancer fatalities.
Risk of cancer fatality and number of cancer fatalities are per year of operation.
LLNL = Lawrence Livermore National Laboratory; MEI = maximally exposed individual; mrem/yr = millirems per year.

MEI and offsite population dose were calculated using the CAP88 computer model (CAP88-PC2000), as described in Section C.4.2.2. Noninvolved worker doses were calculated in a similar manner as the offsite population doses; the exposure of spatially distributed onsite workers to major site releases was estimated using the CAP88 computer model. Involved worker doses were projected based on recent continuing operations and projections of specific additional operation impacts on involved workers.

C.3.4 Combined Risks

In assessing the safety of an operation it is important to compare the harm that may be caused by ionizing radiation with that caused by other agents (e.g., chemicals). The International Commission on Radiological Protection considers that any formal solution for adding the effects are impossible since "the various harmful effects of radiation are not only different in kind, but are likely to be regarded as of different importance by different individuals." Furthermore, radiation in combination with other physical and chemical agents may exhibit additive, synergistic, or even antagonistic effects depending on the agents and the conditions of exposure. Similarly, human exposure to carcinogenic chemicals in combination with other noncarcinogenic chemicals may result in additive, synergistic, or antagonistic effects, depending on the chemicals and the conditions.

In general, whole-body radiation appears to be carcinogenic for many, if not most, tissues of the body whereas specific carcinogenic chemicals typically induce cancers in a comparatively small number of target tissues. The cancers developed by both radiation and chemical carcinogens are indistinguishable from those induced by other causes, and their induction can only be inferred on statistical grounds.

Because of these limitations and the low probabilities of health effects associated with the operation of LLNL, no attempt was made to combine the risks from ionizing radiation with those from other agents.

C.4 PUBLIC HEALTH

Measures would be taken to minimize exposures to the public that might occur from operations at LLNL. All releases would be limited to comply with the regulatory requirements of DOE Orders and with Federal laws and regulations identified in Section C.1. There are no significant sources of external radiation exposure to the public from site operations at LLNL.

Radionuclide releases are minimized through engineering (e.g., high-efficiency particulate air filters, tritium removal systems, and water discharge retention tanks) and administrative (e.g., worker training, inventory limits) controls. Releases to the sewer system are minimized by engineering controls such as retention tanks and blocking connections to sewer drains, and administrative controls such as limiting inventories, worker training, and posting notices on sinks that discharge directly into the sewer system.

Under normal operations, air is the only pathway that poses a potential for health impacts to the public from radionuclide emissions. Other pathways are incomplete in that either the transport pathway (the environmental medium by which a contaminant is moved, e.g., water, soils) or the exposure pathway (e.g., drinking water, dermal contact with soil) is not viable. The specific resource sections, Section 4.10, Air Quality, and Section 4.11, Water, describe the existing conditions of the environmental media.

The major radionuclide contributor to dose from the Livermore Site is tritium. None of the Livermore Site facilities monitored for gross alpha and beta had emissions above minimum detectable limits in the most recent year from which results are available (2002) (LLNL 2003l). At Site 300, practically all contributions to dose are from depleted uranium.

C.4.1 Environmental Monitoring

Although LLNL's mission has been fundamentally one of scientific research, as an institution it has been ever mindful of its responsibilities for protecting the ES&H of its employees, the environment, and members of the public. As stated in the ES&H Manual, "it is the Laboratory's ES&H policy to perform work in a manner that protects the health and safety of employees and the public, preserves the quality of the environment, and prevents property damage. The environment, safety, and health are to be priority considerations in the planning and execution of all work activities at LLNL. Furthermore, it is the policy of LLNL to comply with applicable ES&H laws, regulations, and requirements."

To verify that LLNL is meeting these requirements, LLNL currently monitors the ambient air, water, and soil, and air and liquid effluents, as well as vegetation and products, for numerous radiological and nonradiological materials. LLNL complies with all Federal, state, and local environmental permitting requirements, including those imposed by listing as a Superfund site on the National Priorities List (LLNL 2003l).

The purpose of this section is to provide an overview of the environmental monitoring program conducted by LLNL. The Environmental Protection Department conducts an extensive program of effluent and surveillance monitoring of all environmental media (i.e., air, soil, surface water, groundwater, rain, sewage, foodstuffs, and direct radiation) and evaluates the impacts from LLNL operations on the environment and public health.

The program activities are mandated by the Federal *Clean Water Act*, National Emissions Standards for Hazardous Air Pollutants (NESHAP) regulations, parallel state and local regulations, as well as DOE directives. The principal activities include:

- Establishing and maintaining monitoring networks, sampling locations, and methods and procedures for data collection
- Collecting and analyzing environmental monitoring samples
- Maintaining and operating the sewer monitoring system
- Determining compliance with environmental laws and regulations governing NESHAP emissions and discharges of water and wastewater to the environment
- Assessing risks to the environment and the public from LLNL operations
- Documenting the results of the environmental monitoring effort in the annual environmental report

There is a comprehensive environmental monitoring program to assess the effectiveness of effluent control measures, to assess compliance with applicable environmental regulations, and to estimate the impact of operations on the environment. The environmental monitoring programs are conducted in accordance with DOE guidance. All environmental media that could be impacted by LLNL operations are monitored. LLNL maintains a comprehensive environmental monitoring program to evaluate compliance with local, state, and Federal laws and regulations and to ensure that human health and the environment are protected from site emissions. Air and sewage effluent, surface water, rain, groundwater, soil, vegetation, and foodstuff samples are collected and analyzed. The results are reported annually to DOE, Federal, state, and local regulatory authorities. Table C.4.1–1 illustrates the breadth of the radiological monitoring program. The table is not meant to be all-inclusive. During 2002, 11,877 samples were taken and 212,689 analytes were tested (LLNL 2003l). Further details of the monitoring system and results can be found in the Site Annual Environmental Report (LLNL 2003l).

Figure C.4.1–1 presents historical trends for the monthly 24-hour composite sample results from 1994 through 2002 for eight of the nine regulated metals; cadmium is not presented because it is typically not detected. All of the monthly 24-hour composite samples were in compliance with the permit discharge limits for the sewer monitoring system. As noted in both 2000 and 2001, arsenic continues to show on occasional elevated concentration, although it never exceeds 20 percent of the effluent pollutant limit. Both silver and lead each exhibit a single elevated monthly concentration during calendar year 2002; but neither exceeds 50 percent of their respective effluent pollutant limits. The other metals have no discernible trends in their concentrations (LLNL 2003l).

Effluent and Air Monitoring

Two types of air monitoring are performed. Air effluent monitoring involves extracting a measured volume of air from the exhaust of a facility or process and subsequently collecting particles by filters or vapors by a collection medium. As of 2002, LLNL operated 77 air effluent sampling systems at 7 facilities at the Livermore Site and 1 system at Building 801A at Site 300. LLNL reassesses the need for effluent monitoring annually or more often if warranted by new or modified operations. In addition, the U.S. Environmental Protection Agency requires that air effluents be monitored if the potential for offsite dose is greater than 0.1 millirem per year (1 percent of regulatory limit). Some facilities use real-time alarm monitors at discharge points to provide faster notification in the event of a radioactivity release; these alarms are not included in the above sampling system total. The monitoring results are used in calculating dose to offsite individuals to demonstrate compliance with regulations and to ensure protection of human health and the environment. Facilities that are not monitored are still considered in the dose calculations by considering their radionuclide inventories, release fractions, and emission control factors.

TABLE C.4.1–1.—*Environmental Radiological Monitoring Program*

Medium	Location	Analyte	Sampling Locations
Air effluent	Livermore Site	Gross alpha, beta	69 monitors
		Tritium (total, gaseous, water vapor)	8 monitors
Ambient air	Livermore Site	Gross alpha, beta, gamma, plutonium-239+240, uranium-235, uranium-238, beryllium	6 sites
		Gross alpha, beta, plutonium-239+240	1 site
		Tritium	6 sites
	Livermore Valley	Tritium	1 site
		Gross alpha, beta, plutonium-239+240, tritium	5 sites
		Gross alpha, beta, plutonium-239+240	4 sites
	Site 300	Gross alpha, beta, gamma, uranium-235, uranium-238, plutonium-239+240, beryllium	3 sites
		Gross alpha, beta, gamma, uranium-235, uranium-238, plutonium-239+240	4 sites
		Gross alpha, beta, uranium-235, uranium-238, Tritium	1 site
	Tracy	Gross alpha, beta, uranium-235, uranium-238, beryllium	1 site
Sewage	Livermore Site	Tritium, alphas, betas, pH, metals, others	Sewage Monitoring Station
		pH	Upstream pH Monitoring Station
		As applicable	33 water retention tanks
Stormwater	Livermore Site	Gross alpha, gross beta, tritium, plutonium, metals water quality parameters, fish bioassay, others	10 locations + construction sites
	Site 300	Gross alpha, gross beta, tritium, uranium, explosives, metals, water quality parameters, others	9 locations + construction sites
Rainfall	Livermore Site	Tritium	7 sites
	Livermore Valley	Tritium	10 sites
	Site 300	Tritium	2 sites
	Site 300 offsite	Tritium	1 site
Retention basin	Livermore Site	Gross alpha, gross beta, tritium, metals, water quality parameters, fish bioassay, others	4 sites + vertical profiles
Others (drinking water sources, swimming pool, etc.)	Livermore Site	Gross alpha, gross beta, tritium	2 sites
	Livermore Valley	Gross alpha, gross beta, tritium	10 sites
	Site 300	Gross alpha	2 sites
Groundwater	Livermore Site	Gross alpha, gross beta, specific isotopes (e.g., americium-241, plutonium isotopes, radon-222, tritium, uranium isotopes), metals, inorganic and organic chemicals, etc.	~25 onsite and 10 along perimeter
	Livermore Valley	Same as above	23
	Site 300	Gross alpha, gross beta, uranium, tritium, organics, nitrate, etc.	20+ surveillance wells and numerous compliance wells
	Site 300 offsite	Same as above	12

TABLE C.4.1–1.—*Environmental Radiological Monitoring Program (continued)*

Medium	Location	Analyte	Sampling Locations
Soil and sediments	Livermore Site	Gamma emitting radionuclides (e.g., thorium-232), plutonium, tritium (sediments), metals, organics, PCBs (vadose zone)	6 each surface soil, sediment, vadose zone
	Livermore Valley (soil only)	plutonium and gamma emitting nuclides (e.g., thorium-232)	13
	Site 300 (soil only)	Gamma emitting radionuclides, uranium, beryllium	14
Vegetation	Livermore Site	Tritium	7 sites
	Livermore Valley	Tritium	7 sites
	Site 300	Tritium	4 sites
Wine	Livermore Valley	Tritium	12 store purchased bottles
External radiation	Livermore Site	Gamma radiation (using TLDs)	14 sites along perimeter
	Livermore Valley	Same as above	22 sites
	Site 300	Same as above	9 perimeter + 4 interior locations
	Site 300 offsite	Same as above	2 sites
	Tracy	Same as above	2 sites

Source: LLNL 2003l.
PCBs = polychlorinated biphenyls; TLDs = thermoluminescent dosimeter.

Ambient air monitoring and effluent monitoring use air extraction and collection media for sampling particulates and vapors, respectively. All monitors are continuous, with particulate samples collected weekly and tritium samples biweekly. Fourteen Livermore Site samplers surround the site, with five additional internal site locations to sample diffuse (i.e., from soil and water) releases. Livermore Valley sites are located in all directions from the Livermore Site. The Site 300 network consists of nine samplers around the site and near firing tables, with an additional site in downtown Tracy.

LLNL performs continuous air effluent sampling of atmospheric discharge points at several facilities. LLNL assesses air effluent emissions from facility operations to evaluate compliance with local, state, and Federal regulations and to ensure that human health and the environment are protected from hazardous and radioactive air emissions. Enforcement authority of the *Clean Air Act* regulations for nonradiological air emissions has been delegated to the local air districts including the Bay Area Air Quality Management District (BAAQMD) for the Livermore Site and the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD) for Site 300. Applicable regulations and permitting requirements are contained in BAAQMD Regulations 1-12 for the Livermore Site and SJVUAPCD Rules 1010 through 9120 for Site 300.

The Livermore Site currently emits approximately 109 kilograms per day of criteria air pollutants; e.g., nitrogen oxides, sulfur oxides, particulate matter (PM_{10}), carbon monoxide, and lead, as defined by the *Clean Air Act*. The largest sources of criteria pollutants at Livermore Site are surface coating operations, internal combustion engines, solvent operations, and, when grouped together, oil and natural gas-fired boilers (see Table C.4.1–2).

TABLE C.4.1–2.—*Lawrence Livermore National Laboratory Nonradioactive Air Emissions, 2002*

Pollutant	Estimated Releases (kg/day)	
	Livermore Site	Site 300
Organics/volatile organics	16	0.23
Nitrogen oxides	67	1.1
Carbon monoxide	17	1
Particulates (PM_{10})	6.1	0.09
Sulfur oxides	2.8	0.07

kg/day = kilograms per day.

When comparing the estimated releases from exempt and permitted sources of air pollutants at the Livermore Site with daily releases of air pollutants for the entire Bay Area, LLNL emissions are very low. For example, the total emissions of nitrogen oxides released in the Bay Area for 2002 were approximately 8.3×10^4 kilograms per day, compared with an estimate for LLNL releases of 67 kilograms per day for the Livermore Site or 0.08 percent of total Bay Area emissions from stationary sources. The BAAQMD estimate for reactive organic emissions was 9.8×10^4 kilograms per day for 2002, versus the Livermore Site's estimated releases of 16 kilograms per day or 0.02 percent of total Bay Area emissions from stationary sources.

Certain operations at Site 300 require permits from SJVUAPCD. The total estimated air emissions from operations, permitted and exempt air sources, at Site 300 during 2002 are given in Table C.4.1–2. The largest sources of criteria pollutants at Site 300 include internal combustion engines, boilers, a gasoline-dispensing operation, open burning, paint spray booths, drying ovens, and soil-vapor-extraction operations.

Nonradioactive air effluents are very small compared with emissions in surrounding areas, are well below standards, and are not a threat to the environment or public health.

The primary nonradiological effluent monitored at LLNL is beryllium. Livermore Site beryllium monitoring continued in 2002 at all except one perimeter locations. To satisfy beryllium reporting requirements and determine the effects of LLNL's beryllium operations, LLNL conducted a technical assessment of the beryllium monitoring locations at Site 300 in 1997. Although there is no requirement to sample for beryllium at Site 300, LLNL has decided, as a best management practice, to continue beryllium monitoring at three locations onsite and at one location in the city of Tracy.

The concentrations of beryllium at both sites can be attributed to resuspension of surface soil containing naturally occurring beryllium. Local soils contain approximately 1 part per million of beryllium, and the air of the Livermore area and the Central Valley typically contains 10 to 100 micrograms per cubic meter of particulates. Using a value of 50 micrograms per cubic meter for an average dust load and 1 part per million for beryllium content of dust, a conservative airborne beryllium concentration of 50 picograms per cubic meter can be predicted. The overall annual medians for the Livermore Site and Site 300 are 9.6 picograms per cubic meter and 9.0 picograms per cubic meter, respectively. These data are lower than predicted, well below standards, and do not indicate the presence of a threat to the environment or public health (LLNL 2003l).

Sewage Sampling

LLNL tightly controls its discharges to the sanitary sewer. LLNL operates under two wastewater discharge permits issued by the Livermore Water Reclamation Plant. They are the general site-wide permit and the groundwater discharge permit. The general site-wide permit is the most comprehensive, covering all discharges except groundwater.

LLNL's sanitary sewer concerns in the past have involved radioactive waste, organic compounds, metals, and pH. Radioactive waste containing tritium is especially tightly controlled because it cannot be treated; pH is the most common and ongoing problem. LLNL recognizes that any discharge to the sewer can be a potential problem. Even seemingly insignificant amounts of chemicals and metals in wastewater can pose a hazard to unsuspecting LLNL and Livermore Water Reclamation Plant employees working on the sewer system or at the treatment plant. Contaminated water can cause direct harm to the environment, upset the city of Livermore's treatment plant operations, and cause a violation of the discharge limits that LLNL is required to meet.

ES&H Team and Water Guidance and Monitoring Group environmental analysts provide support for determining whether new waste streams can be safely discharged to the sanitary sewer.

Reducing the likelihood of prohibited discharges requires that LLNL's waste stream be tightly managed. All LLNL employees working in operations that produce wastes with regulated constituents are responsible for managing their discharges to the sanitary sewer system. The primary focal points of effective waste stream management are pollution prevention; site discharge limits and points where compliance determinations are made; and treatment, control, and maintenance options.

Effective source reduction, reuse, and recycling are the three mechanisms that drive the pollution prevention efforts at LLNL. The optimal approach is that pollution prevention efforts should be focused on material substitutions so the wastewater generated is no longer regulated, or processes should be changed so less or no wastewater is generated.

Employees and organizations that generate any pollutant regulated under the sanitary sewer discharge permit and that are interested in pollution prevention are require to contact their program or facility pollution prevention representative, or their ES&H Team environmental analyst. These individuals provide assistance in determining whether waste stream minimization or segregation techniques would be helpful for a particular process. Pollution prevention remedies can include using less hazardous chemicals, minimizing rinsewater, installing filtration units, converting to alternative processes, and many other approaches.

Specific discharge limits for regulated contaminants are identified in the ES&H Manual, Appendix B of Document 32.4, "Discharges to the Sanitary-Sewer System," (LLNL 2000i). This appendix shows only the most common types of potential discharges from LLNL along with the applicable regulatory limits. The effluents and constituents highlighted in Appendix B of Document 32.4 include metals, the total toxic organic content of discharges, and Federal standards for pollutants regulated under the metal finishing and electrical and electronic component categories. The list is not comprehensive but identifies the more common substances that are regulated. Other constituents of concern to the Livermore Water Reclamation Plant, but not hazardous (e.g., biological oxygen demand and total dissolved solids), may be evaluated by the Waste Guidance and Monitoring Group environmental analyst on a case-by-case basis to determine acceptability for release. Of particular interest may be tanks with residual solvents.

LLNL's most common and ongoing problem related to sanitary sewer discharges has been compliance with the allowable pH range. The pH levels of all discharges to the sanitary sewer from individual processes at LLNL must be between 5 and 10. Wastewater with a pH of less than 2 or greater than 12.5 is a hazardous waste by regulatory definition and must be treated by the RHWM Division. To provide more controls on discharge pH management, warning labels with contact information are posted on every sink and retention tank onsite to maximize employee awareness.

Water may not be added to a waste stream solely for the purpose of diluting the waste. The city of Livermore's Municipal Code specifies that "No user shall ever increase the use of process water or, in any way, attempt to dilute a discharge as a partial or complete substitute for adequate treatment to achieve compliance with the limitations contained in the Federal Categorical Pretreatment Standards, or in any other pollutant-specific limitation developed by the city or state," (Livermore Municipal Code §13.32.130).

LLNL is the single largest source of sanitary sewage processed by the Livermore Water Reclamation Plant. LLNL's collection system handles sewage from both the Livermore Site and from Sandia National Laboratories/California. Together, LLNL and Sandia National Laboratories/California produce an average of 250,000 gallons of sewage each day. After treatment, wastewater is discharged into San Francisco Bay and sludge is disposed of in local landfills. Because of the many industrial processes performed at LLNL and Sandia National Laboratories/California, and the wide range of hazardous and radioactive materials handled, the two facilities have the potential to adversely affect operations of the treatment plant. To prevent such occurrences, LLNL has developed comprehensive sewer discharge control and monitoring programs.

LLNL operates retention tank systems to collect wastewater that may contain constituents in excess of sanitary sewer discharge limits, store it temporarily until an appropriate disposal method is determined, and possibly treat the wastewater if it is outside sewer discharge limits or is hazardous waste. Waste Guidance and Monitoring Group assists in obtaining required permits for retention tank systems, interfacing with regulators, reviewing new designs, overseeing proper installation, operating systems properly, testing systems, and preparing required reports.

LLNL performs two types of monitoring: compliance monitoring and surveillance monitoring. Compliance monitoring is performed at specified frequencies for those constituents required by permit or law. Compliance monitoring is established to verify that LLNL's discharges are consistent with the two types of discharge limits established in the wastewater discharge permit: general prohibitions that are designed to protect the Publicly Owned Treatment Works but do not target specific pollutants and have no numerical limits and specific prohibitions that target individual pollutants and usually have a numerical limit.

Sampled wastewater is released from retention tanks only after analytical laboratory measurements show pollutant levels within discharge limits. In 2002, there were 33 water retention tank systems in use at the Livermore Site, with additional collection units at Site 300. If pollutant levels exceed limits, the wastewater is either treated to levels within limits or shipped to offsite treatment or disposal facilities. The sewer monitoring station continuously collects samples for metals, radioactivity, toxic chemicals, and water-quality parameters. If concentrations above warning levels are detected, an alarm registers and the flow is diverted to the sewer diversion facility. All alarms are evaluated and appropriate actions taken. In addition, LLNL monitors pH at the upstream pH monitoring station. This upstream monitoring allows for earlier detection of problems and diversion if necessary. Diverted sewage is either treated to meet discharge limits or shipped offsite for disposal.

Under its permit, LLNL is required to monitor its sanitary sewer effluent for flow, pH, radioactivity, and regulated metals. LLNL also collects and analyzes samples for all other regulated constituents, such as organic compounds and biological oxygen demand.

The second type of monitoring, surveillance monitoring, is performed by LLNL at intervals for a range of contaminants of potential concern in response to DOE orders.

Table C.4.1–3 presents monthly average concentrations for all regulated metals in LLNL's sanitary sewer effluent for 2002. The averages were obtained by flow-proportional weighting of the analytical results for the weekly composite samples collected each month. Each result was weighted by the total flow volume for the period during which the sample was collected. The results are generally typical of the values seen from 1994 to 2001. Figure C.4.1–1 presents historical trends for monthly 24-hour composite sample results from 1994 through 2002 for eight of nine regulated metals (cadmium is usually not detected). These historical trends are typically well below their respective effluent pollutant limits.

The concentrations measured in the routine analysis of LLNL sewage samples collected once a week (7-day composite sample) and once a month (24-hour composite samples) are presented for eight of nine regulated metals as a percentage of the corresponding effluent pollutant limit in Figure C.4.1–2; cadmium results are not presented because the metal was not detected above the practical quantitation limit of 0.005 milligrams per liter in any of the weekly or monthly samples. The effluent pollutant limit is equal to the maximum pollutant concentration allowed per 24-hour composite sample, as specified by the LLNL wastewater discharge permit. When a weekly sample concentration is at or above 50 percent of its effluent pollutant limit, all daily (24-hour composite) samples collected in the Safety Management System corresponding to the weekly sample period must be analyzed to determine if any of their concentrations are above the effluent pollutant limit. Two elevated monthly concentrations, silver at 50 percent of its effluent pollutant limit in April and lead at 30 percent of its effluent pollutant limit in August, are shown in Figure C.4.1–2. In addition, five weekly concentrations (Figure C.4.1–2) are at or above 50 percent of their respective effluent pollutant limits.

The elevated arsenic values, reported at 67 percent of the effluent pollutant limit for the weeks of June 5–12 and June 12–17, can be attributed to an analytical artifact resulting from matrix interface. The actual arsenic concentrations for those two weeks were reported as <0.04 milligrams per liter, a factor of 20 greater than the typical practical quantitation limit for arsenic of 0.002 milligram per liter. Lead concentrations in daily samples from the week of August 1–7, 2002, show two samples (August 3 at 0.226 milligram per liter and August 6 at 0.208 milligram per liter, representing effluent collected during the prior 24-hour periods) exceeding the 0.2-milligram-per-liter permitted discharge limit for lead. In October 2002, the Livermore Water Reclamation Plant issued a warning notice as a result of these exceedances of the effluent pollutant limit for lead. No corrective action was suggested or required, because LLNL had demonstrated a return to compliance and that sufficient measures had been taken to investigate this inadvertent discharge. The results of similar analyses showed no chromium concentrations in the August 1–7 daily samples, or lead concentrations in the November 21–27, 2002, daily samples above their respective effluent pollutant limits. Although each of these incidents was reported to the Livermore Water Reclamation Plant, none represented a threat to the integrity of the Livermore Water Reclamation Plant operations (LLNL 2003l).

Detections of anions, metals, and organic compounds and summary data concerning other physical and chemical characteristics of the sanitary sewer effluent are provided in Table C.4.1–4. All analytical results are provided in the Data Supplement, Table C.4.1-4. Although monthly (24-hour) composite samples were analyzed for hydroxide alkalinity, beryllium, and cadmium, these analytes were not detected in any sample taken during 2002 and are not presented in Table C.4.1–4. Similarly, analytes not detected in any of the 2002 monthly grab samples are not listed in Table C.4.1–4. These monthly monitoring results for physical and chemical characteristics of the LLNL sanitary sewer effluent are typical of those seen in previous years.

Table C.4.1–3 presents monthly average concentrations and summary statistics for all regulated metals monitored in LLNL's sanitary sewer effluent. The annual median concentration for each metal is shown and compared to the discharge limit. In 2002, the median concentration of monthly average values remained essentially unchanged from the corresponding 2001 values for all nine regulated metals. Medians of the monthly average concentration were less than 10 percent of the limits for all but copper, lead, and zinc, which were at 17 percent, 11 percent, and 13 percent, respectively.

Although median values of monthly average metal concentrations have remained well below discharge limits (see Table C.4.1–3) and only one monthly (24-hour) composite sample showed any regulated metal above one-third of the respective effluent pollutant limit; i.e., silver was detected in the April monthly composite at 0.10 milligram per liter or 50 percent of its effluent pollutant limit, three weekly metal sample concentrations were identified for additional analyses based on 7-day composite results at or near the action limit (see Figure C.4.1–2). As discussed above, the two elevated weekly arsenic values can be attributed to an analytical artifact. Action limit investigations examined a weekly sample in August; i.e., for chromium and lead at 69 percent and 55 percent of their respective effluent pollutant limits, and a weekly sample in November; i.e., for lead at 50 percent of its effluent pollutant limit. The daily samples that correspond to the appropriate 7-day composite sampling periods were submitted to an offsite contract analytical laboratory for analysis.

Table C.4.1–4 presents summary results and statistics for monthly monitoring of physical and chemical characteristics of LLNL's sanitary sewer effluent. The results are generally similar to typical values seen in previous years for the two regulated parameters (cyanide and total toxic organics) and all other nonregulated parameters. Cyanide was detected only in the January 2002 semiannual sample (at 0.024 milligram per liter, which is below the 0.04-milligram-per-liter permit limit). This constituent was below analytical detection limits (0.02 milligram per liter) in both the second semiannual (July 2002) sampling and the annual (October 2002) joint LLNL/Livermore Water Reclamation Plant cosampling events. The monthly total toxic organics values ranged from less than 0.010 milligram per liter to 0.10 milligram per liter (median was 0.039 milligram per liter), well below the total toxic organics permit limit of 1.0 milligram per liter. In addition to the organic compounds regulated under the total toxic organics standard, seven nonregulated organics were also detected in LLNL's sanitary sewer effluent: four volatile organic compounds (2-butanone, acetone, Freon 113, and styrene) and three semivolatile organic compounds (benzoic acid, benzyl alcohol, and m- and p-Cresol).

TABLE C.4.1–4.—*Monthly Results for Physical and Chemical Characteristics of the Lawrence Livermore National Laboratory Sanitary Sewer Effluent, 2002*[a]

	Detection Frequency [b]	Minimum	Maximum	Median	IQR
24-Hour Composite Sample Parameter (mg/L)					
Alkalinity (mg/L)					
Bicarbonate alkalinity (as $CaCO_3$)	12 of 12	175	300	250	24.0
Carbonate alkalinity (as $CaCO_3$)	2 of 12	<5	55.0	<5	[c]
Total alkalinity (as $CaCO_3$)	12 of 12	230	300	250	22.5
Anions (mg/L)					
Bromide	10 of 12	<0.1	1.1	0.25	[c]
Chloride	12 of 12	41	114	61	28
Fluoride	10 of 12	<0.05	2.3	0.11	[c]
Nitrate (as N)	1 of 12	<0.1	<1	<0.44	[c]
Nitrate (as NO_3)	1 of 12	<0.04	<4.4	<4.4	[c]
Nitrate plus Nitrite (as N)	2 of 12	<0.1	<1	<1	[c]
Nitrite (as N)	8 of 12	<0.02	0.33	0.19	[c]
Nitrite (as NO_2)	8 of 12	<0.065	1.1	0.63	4.3
Orthophosphate	12 of 12	15	23	20	2.3
Sulfate	12 of 12	12	19	15	
Nutrients (mg/L)					
Ammonia nitrogen (as N)	12 of 12	43	56	47	5.0
Total Kjeldahl nitrogen	12 of 12	49	95	60	11
Total phosphorus (as P)	12 of 12	6.8	14	9.8	2.6
Oxygen demand (mg/L)					
Biochemical oxygen demand	12 of 12	100	810	333	107
Chemical oxygen demand	12 of 12	145	1,780	602	121
Solids (mg/L)					
Settleable solids	12 of 12	4	90	40	11.3
Total dissolved solids	12 of 12	165	413	256	78.5
Total suspended solids	12 of 12	88	650	385	138
Volatile solids	12 of 12	140	913	480	142
Total metals (mg/L)					
Aluminum	12 of 12	0.30	0.80	0.49	0.16
Calcium	12 of 12	15	27	18	2.3
Iron	12 of 12	1.0	2.5	1.6	0.30
Magnesium	12 of 12	2.5	3.0	2.8	0.15
Potassium	12 of 12	19	26	22	2.0
Selenium	2 of 12	<0.002	<0.02	<0.002	[c]
Sodium	12 of 12	35	87	47	15
Total organic carbon	12 of 12	39	56	53	6.3
Tributyltin[d]	1 of 2	<6	10	[e]	[c]

TABLE C.4.1–4.—*Monthly Results for Physical and Chemical Characteristics of the Lawrence Livermore National Laboratory Sanitary Sewer Effluent, 2002[a] (continued)*

	Detection Frequency [b]	Minimum	Maximum	Median	IQR
Grab Sample Parameter					
Semivolatile organic compounds (µg/L)					
Benzoic acid	10 of 12	<10	110	21	39
Benzyl alcohol	10 of 12	<2	1900	12	49
Bis(2-ethylhexyl)phthalate	10 of 12	<5	32	8.1	4.7
Butylbenzylphthalate[f]	2 of 12	<2	9.4	<2	[c]
Diethylphthalate[f]	3 of 12	<2	16	<2	[c]
Diethylphthalate[f]	12 of 12	6.2	35	21	15
Phenanthrene[f]	1 of 12	<2	2.3	<2	[c]
Phenol[f]	7 of 12	<2	29	2.8	[c]
m- and p-Cresol	11 of 12	<2	450	19	26
Total cyanide (mg/L)[g]	1 of 3	<0.02	0.024	[f]	[d]
Oil and grease (mg/L)[h]	8 of 8	12	37	28	17
Volatile organic compounds (µg/L)					
1,2-Dichloroethene[f]	1 of 12	<0.5	0.58	<0.5	[c]
1,4-Dichlorobenzene[f]	1 of 12	<0.5	0.67	<0.5	[c]
2-Butanone	1 of 12	<20	52	<20	[c]
Acetone	12 of 12	140	560	310	190
Bromoform[f]	1 of 12	<0.5	0.87	<0.5	[c]
Chloroform[f]	12 of 12	5.7	17	11	3.9
Freon 113	1 of 12	<0.5	0.16	<0.5	[c]
Methylene chloride[f]	3 of 12	<1	3.5	<1	[c]
Styrene	1 of 12	<0.5	0.59	<0.5	[c]
Toluene[f]	2 of 12	<0.5	0.67	<0.5	[c]

Source: LLNL 2003l.

[a] The monthly sample results plotted in Figure C.4.1–2 are not reported in this table.

[b] The number of times an analyte was positively identified, followed by the number of samples that were analyzed (generally 12, one sample for each month of the year).

[c] When the detection frequency is less than or equal to 50 percent, there is no range, or there are fewer than four results for a sample parameter, then the interquartile range is omitted.

[d] Sampling for this parameter is required on a semiannual rather than a monthly basis.

[e] When there are fewer than four results for a sample parameter, the median is not calculated.

[f] Priority toxic pollutant parameter used in assessing compliance with the total toxic organic permit limit of 1 milligrams per liter (1000 picos per liter) issued by the Livermore Water Reclamation Plant.

[g] Sampling for this parameter is required on a semiannual (January and July) rather than a monthly basis. An additional sample was taken I October during the annual co-sampling event with the LWRP.

[h] The requirement to sample for oil and grease has been suspended until further notice based on the LWRP letter of April 1, 1999. LLNL collects these samples (four per day) semiannually as part of the source control program.

IQR = Interquartile range; mg/L = milligrams per liter; µg/L = micrograms per liter; LWRP = Livermore Water Reclamation Plant; LLNL = Lawrence Livermore National Laboratory.

In 2002, the Safety Management System continuous monitoring system detected six inadvertent discharges outside the permitted pH range of 5 to 10. Four of these events, one with a pH below 5 and three with a pH above 10, were completely captured by the sewer diversion facility. The other two events, both with a pH below 5, occurred off-hours when the upstream pH monitoring station was offline. As a result, two front-end volumes (small quantity) of low pH sanitary effluent were released to the Livermore Water Reclamation Plant system before a diversion to the sewer diversion facility could be made. The Livermore Water Reclamation Plant was immediately notified of both low pH discharges; however, neither incident represented a threat to the integrity of the operations of the Livermore Water Reclamation Plant, nor were these events considered enforceable exceedances of permit conditions. The lowest pH recorded for effluent contained in the first release, February 9, 2002, was 4.6; the second release, October 13, 2002, contained effluent with a pH as low as 4.96.

Monitoring results for 2002 reflect an effective year for LLNL's sewerable water discharge control program and indicate no adverse impact to the Livermore Water Reclamation Plant or the environment from LLNL sanitary sewer discharges. Overall, LLNL achieved greater than 99 percent compliance with the provisions of its wastewater discharge permit (LLNL 2003l).

Water Monitoring

In accordance with Federal, state, and internal requirements, LLNL monitors surface water quality at and around the Livermore Site, surrounding regions of the Livermore Valley and Altamont Hills, and Site 300. Specifically in the Livermore vicinity, LLNL monitors reservoirs and ponds, the Livermore Site swimming pool, the Drainage Retention Basin, rainfall, tap water, stormwater runoff, and receiving waters. At Site 300 and its vicinity, surface water monitoring encompasses rainfall, cooling tower discharges, drinking water system discharges, stormwater runoff, and receiving waters.

In addition to surface water, LLNL also regularly samples and analyzes groundwater in the Livermore Valley and in the Altamont Hills. LLNL maintains compliance and surveillance groundwater monitoring programs to comply fully with environmental regulations, applicable DOE orders, and the requirements of the Groundwater Protection Management Program. The objectives of the groundwater monitoring programs are to measure compliance with waste discharge requirements and postclosure plans (compliance monitoring) and to assess the impact, if any, of LLNL operations on groundwater resources (surveillance monitoring).

DOE O 5400.1 requires all DOE facilities to prepare a Groundwater Protection Management Program that describes the site's groundwater regime, areas of known contamination, remediation activities, programs to monitor groundwater, and means to monitor and control potential sources of groundwater contamination. Considerable remediation monitoring of groundwater is carried out under CERCLA restoration efforts.

A wide range of analytes is monitored to assess the impact, if any, of current LLNL operations on local groundwater resources. Because surveillance monitoring is geared to detecting substances at very low concentrations in groundwater, it can detect contamination before it significantly affects groundwater resources. Wells at the Livermore Site, in the Livermore Valley, and at Site 300 in the Altamont Hills are included in LLNL's surveillance monitoring plan. Historically, the surveillance and compliance monitoring programs have detected elevated concentrations of various metals, nitrate, perchlorate, and uranium-238 in groundwater at Site 300. Subsequent CERCLA studies have linked several of these contaminants, including uranium-238, to past operations, while other contaminants are the objects of continuing study. Present-day administrative, engineering, and maintenance controls at both LLNL sites are specifically tailored to prevent accidental releases of chemicals to the environment.

The Compliance Groundwater Monitoring Program at Site 300 complies with numerous Federal and state controls. Compliance monitoring of groundwater is required at Site 300 in order to satisfy state-issued permits associated with closed landfills containing solid wastes and with continuing discharges of liquid waste to surface impoundments, sewage ponds, and percolation pits. Compliance monitoring is specified in Waste Discharge Requirement orders issued by the Central Valley Regional Water Quality Control Board and in landfill closure and post-closure monitoring plans (LLNL 2003l).

Stormwater

Stormwater is monitored to demonstrate compliance with permit requirements and to ensure contamination prevention. Stormwater is sampled at least twice a year and visually inspected more often. Stormwater is sampled for radioactivity; metals; various water quality parameters, such as dissolved oxygen, pH, and total dissolved solids; toxic chemicals; and polychlorinated biphenyls (PCBs). Site 300 sampling includes explosives and related chemicals, such as ammonia. Stormwater is sampled both upstream and downstream of both LLNL sites. Run-on to the Livermore Site includes runoff contamination from other sources, such as agricultural land and parking lots. Site 300 stormwater sampling targets specific industrial areas from which the stormwater originates on the site. Runoff from construction projects is also sampled. Construction site stormwater sampling results indicate that the NIF construction site is not contributing PCBs to stormwater runoff as a result of construction activities (LLNL 2003l).

Rainfall

Emissions from the tritium facility are the primary activity at LLNL with the potential to impact rainwater quality. Rainfall is collected in elevated stainless steel buckets and measured for tritium activity (LLNL 2003l).

Drainage Retention Basin

The Drainage Retention Basin flow is from stormwater and treated groundwater. There are four locations within the basin that are sampled; two locations include vertical profiles in order to ensure discharge limit compliance. Grab samples are taken to measure radioactivity, metals, and water quality parameters. Field measurements of some water quality parameters, such as dissolved oxygen and transparency, are also performed. There is no evidence of adverse environmental impacts resulting from releases from the Drainage Retention Basin. Because of the frequent dry season discharges that occurred from the Drainage Retention Basin, discharges from groundwater treatment facilities, and the wetter rainfall years that occurred from 1997 through 1999, wetland vegetation has increased both upstream and downstream of the Drainage Retention Basin. The federally listed threatened California red-legged frog has colonized these wetland areas (LLNL 2003l).

Cooling Towers

During 2002, the monitoring results for flow, pH, and total dissolved solids from both primary cooling towers show only one value (the total dissolved solids value for the fourth quarter) above the previously established Waste Discharge Requirements 94-131 limits. Because blowdown flow from the cooling towers does not reach Corral Hollow Creek, it is unlikely to have a negative impact on the receiving water. (LLNL 2003l).

Arroyo Las Positas Maintenance Project

Discharges of diverted water related to the Arroyo Las Positas maintenance project did not adversely affect receiving water quality. No receiving water quality criteria were exceeded throughout the duration of the project (LLNL 2003l).

Groundwater

Groundwater is monitored to assess any impact LLNL operations might have on groundwater resources and to measure compliance with discharge requirements and postclosure plans. Surveillance monitoring is geared to detecting substances at very low concentrations so that contamination can be detected before significant impacts occur. Various aquifers are sampled, although surveillance in the uppermost (first impacted) aquifer at each well is the primary focus. Onsite surveillance wells are situated downgradient from and as near as possible to potential release locations.

The overall impacts of Livermore Site and Site 300 operations on offsite groundwaters are minimal. With the exception of volatile organic compounds being remediated under CERCLA at both sites, current LLNL operations have no measurable impacts on groundwaters beyond the site boundaries. Groundwater monitoring at the Livermore Site and in the Livermore Valley indicates that LLNL operations have minimal impact on groundwater beyond the Livermore Site boundary.

During 2002, neither radioactivity nor concentrations of elements or compounds detected in groundwater from any offsite monitoring well were confirmed as exceeding primary drinking water maximum contaminant levels. The maximum tritium activity measured offsite in the Livermore Valley was 92 picocuries per liter, in well 11B1.

Of the Livermore Site monitoring wells, no inorganic data exceeded primary maximum contaminant levels with the exceptions of chromium in monitoring well W-373 and nitrate in monitoring well W-1012. Hexavalent chromium in groundwater in the vicinity of monitoring well W-373 is being removed at Treatment Facilities B and C and concentrations are steadily decreasing.

The LLNL Groundwater Project reports on the treatment of groundwater in the vicinity of the treatment facilities. Concentrations of nitrate in groundwater samples collected from well W-1012 throughout 2002 exceeded California's maximum contaminant levels of 45 milligrams per liter. Nitrate above the maximum contaminant levels has not migrated offsite. LLNL continues to monitor nitrate concentrations at this well and at monitoring well W-571, which is offsite and about 350 meters downgradient from well W-1012. Measurements of arroyo sediments made in 2002 indicate no potential for adverse impacts to groundwater through the arroyos that cross the Livermore Site.

Groundwater monitoring at Site 300 and adjacent properties in the Altamont Hills shows minimal impact of LLNL operations on groundwater beyond the site boundaries. Within Site 300, the chemicals detected in groundwater beneath the explosives process area will not migrate offsite. Plans to remediate trichloroethylene, explosive compounds such as hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), perchlorates, and nitrate are being implemented under CERCLA auspices. Additionally, LLNL is investigating the distribution and origins of arsenic and zinc in this area. Volatile organic compounds, primarily the solvent trichloroethylene, have been released historically to shallow groundwater at numerous locations at Site 300. With the exception of a small plume in the General Services Area that extends minimally offsite along Corral Hollow Road, all of the trichloroethylene-bearing groundwater is onsite. The plume extending offsite from the Eastern General Services Area is being drawn back to the site by pumping, and the trichloroethylene is being removed from the groundwater. LLNL is investigating various remedial methods to remove depleted uranium from the groundwater adjacent to several source areas within Site 300. Tritiated water has been released to groundwater from several landfills and a firing table in the northwestern part of Site 300. The boundaries of the slowly moving tritiated water plumes lie entirely within the site. CERCLA modeling studies indicate that, given tritium's short half-life of 12.3 years and the relatively slow rate of groundwater flow (5 to 15 meters per year), the activity of the released tritiated water will decrease to several orders of magnitude below the maximum contaminant levels of 20,000 picocuries per liter before it can reach a site boundary and migrate offsite (LLNL 2003l).

Soil Monitoring

The soil and sediment surveillance monitoring performed at LLNL includes work in three areas: surface soil in the Livermore Valley and at Site 300, sediment at the Livermore Site, and vadose zone soils at the Livermore Site. Soil is weathered material, mainly composed of disintegrated rock and organic material that sustains growing plants. Soil can contain pollutants originally released directly to the ground, to the air, or through liquid effluents. DOE guidance for environmental monitoring states that soil should be sampled to determine if there is a measurable, long-term buildup of radionuclides in the terrestrial environment and to estimate environmental radionuclide inventories. The guidance recommends monitoring for radionuclides specific to a particular operation or facility as well as those that occur naturally. Particulate radionuclides are of major interest in the LLNL soil monitoring program because airborne particulate releases are the most likely pathway for LLNL-induced soil contamination.

Sediments are defined as finely divided, solid materials that have settled out of a liquid stream or standing water. The accumulation of radioactive materials in sediments could lead to exposure of humans through ingestion of aquatic species, sediment resuspension into drinking water supplies, or inhalation of dust particles or as an external radiation source. However, the Livermore Site and Site 300 do not have habitats for aquatic species that are consumed by people, nor do they have surface drainage that directly feeds drinking water supplies. Vadose zone soils are sampled to provide information on dissolved constituents in infiltrating water. Sampling locations are chosen based on known contamination or the potential to be affected by LLNL operations. For example, Site 300 locations include sampling around firing tables.

Soils in the vadose zone, the region below the land surface where the soil pores are only partially filled with water, are sampled in arroyo channels at the Livermore Site as part of the Groundwater Protection Management Program. Infiltration of natural runoff through arroyo channels is a significant source of groundwater recharge, accounting for an estimated 42 percent of resupply for the entire Livermore Valley groundwater basin. Soils in the shallow vadose zone are collected and analyzed to provide information about possible constituents that may be dissolved as runoff water infiltrates through the arroyo to the groundwater.

Surface soil sampling near the Livermore Site and Site 300 has been part of a continuing LLNL monitoring program designed to measure any changes in environmental levels of radioactivity and evaluate any increase in radioactivity that might have resulted from LLNL operations. These samples have been analyzed for plutonium and gamma-emitting radionuclides, such as depleted uranium, used in some explosive tests at Site 300. The inclusion of other gamma-emitting, naturally occurring nuclides (potassium-40 and thorium-232) and the long-lived fission product, cesium-137, provides background information and baseline data on global fallout from historical aboveground nuclear weapons testing. In addition, LLNL analyzes Site 300 soils for beryllium, a potentially toxic metal used at this site. Soils in the Livermore vicinity were analyzed for beryllium from 1991 to 1994. However, analysis for beryllium was discontinued at the Livermore Site in 1995, because it was never measured above background values.

Surface soil samples are collected at 19 locations in the Livermore Valley, including 6 sampling locations at the Livermore Water Reclamation Plant, an area of known plutonium contamination, and 14 locations at or near Site 300. The locations were selected to represent background concentrations (distant locations unlikely to be affected by LLNL operations) as well as areas where there is the potential to be affected by LLNL operations. Areas with known contaminants, such as the Livermore Water Reclamation Plant, are also sampled. Site 300 soil sampling locations are established around firing tables and other areas of potential soil contamination.

Sediment samples have been collected from selected arroyos and other drainage areas at and around the Livermore Site since 1988; these locations largely coincide with selected stormwater sampling locations. Sediment sampling locations have not been established at Site 300. The drainage courses at Site 300 are steep, causing flowing water to scour the drainages, which prevents the accumulation of sediment. Because of these conditions, sediment sampling at Site 300 is not warranted.

Vadose zone soil sampling has been conducted at the same selected stormwater sampling locations since 1996. Vadose zone samples were not collected in the Drainage Retention Basin because the liner for the basin prevents migration of materials to the groundwater. The collocation of sampling for these three media facilitates comparisons of analytical results. As with sediment samples, vadose zone samples are not collected at Site 300. Approximately 10 percent of locations are sampled in duplicate; two samples are collected at each location chosen for this sampling. All soil and sediment sampling locations have permanent location markers for reference.

Routine surface soil, sediment, and vadose zone soil sample analyses indicate that the impact of LLNL operations on these media in 2001 has not changed from previous years and remains insignificant. Most analytes of interest or concern were detected at background concentrations or in amounts that could not be measured above detection limits.

The concentrations of radionuclides and beryllium observed in soil samples collected at Site 300 are within the range of previous data and are generally representative of background or naturally occurring levels. The uranium-235/uranium-238 ratios that are indicative of depleted uranium occur near active and inactive firing tables at Buildings 801 and 812. They represent a small fraction of the firing table operations that disperse depleted uranium. The uranium-238 concentrations are below the National Council on Radiation Protection-recommended screening level for commercial sites of 313 micrograms per gram. Historically, some measured concentrations of uranium-238 near Building 812 have been greater than the screening level. A CERCLA remedial investigation is underway at the Building 812 firing table area to define the nature and extent of contamination. Depleted uranium has been detected in soil and groundwater in the area (LLNL 2003l).

Vegetation and Foodstuff Monitoring

LLNL has a vegetation and foodstuff monitoring program to comply with DOE guidance. This guidance states that periodic sampling and analysis of vegetation should be performed to determine if there is a measurable, long-term buildup of radionuclides in the terrestrial environment. LLNL has historically released tritium to the air during routine operations and, occasionally, by accident. Tritium is the only nuclide of interest in the LLNL vegetation and foodstuff monitoring program because tritium is the only radionuclide released from LLNL activities that occurs in detectable concentrations in vegetation and foodstuff. Tritium moves through the food chain as tritiated water and can be rapidly assimilated into plant water and then incorporated into the organic matter of plants through photosynthesis. It can contribute to human radiation dose if it is inhaled, absorbed through the skin, or ingested via vegetables, milk, and meat from animals that are exposed to a tritiated environment.

LLNL has been monitoring tritium in vegetation to some extent since 1966 and has performed vegetation sampling in the vicinity of the Livermore Site and Site 300 as part of a continuing monitoring program since 1971. The monitoring program is designed to measure changes in the environmental levels of radioactivity, to evaluate the environmental effect of LLNL operations, and to calculate potential human doses from tritium in the food chain.

In 1977, LLNL added wine to the LLNL monitoring program. Wine is the most important agricultural product in the Livermore Valley, with a retail value estimated conservatively at $140 million. Although the tritium concentrations in all wines are very low, the sampling data indicate that Livermore Valley wines contain statistically slightly more tritium than do wines from other California wine-producing regions. In the past, other foodstuffs; e.g., cow's milk, goat's milk, and honey, leading to potential doses were also monitored for tritium. At present, however, only tritium concentrations in vegetation and wine are used to assess potential ingestion doses from tritium emitted during LLNL operations, as there are no longer dairy operations near LLNL.

Very low concentrations of tritium may be found in foodstuffs grown near the Livermore Site as a result of LLNL operations. A potential ingestion dose for 2002 that accounts for contributions from tritiated water and organically bound tritium in vegetables, milk, meat, and wine would have been, realistically, less than 0.011 millirems. This estimate is a factor of 27,000 lower than an annual background dose (300 millirems) and a factor of 900 lower than the dose from a typical chest x-ray (10 millirems). Therefore, although tritium levels are slightly elevated near the Livermore Site, doses from tritium ingestion are negligible.

In general, LLNL's impacts on tritium concentrations in vegetation at Site 300 for 2002 were insignificant. With the exception of vegetation from previously identified sites of contamination, the tritium levels at Site 300 were below the limits of detection and comparable to those observed in previous years. The areas where tritium is known to be present in the subsurface soil are well delineated and localized. The calculated maximum potential annual ingestion dose from vegetation at sampling locations, based on the maximum value of 68,000 picocuries per liter, is 1.2 millirems. This dose, based on the conservative modeling assumptions described above, is theoretical, but nevertheless small, because vegetation at Site 300 is not ingested either by people or by livestock (LLNL 2003l).

External Radiation

The main source of environmental external radiation is from cosmic and terrestrial (rocks and soil) sources. External radiation impacts are from gammas. Gamma radiation is measured with thermoluminescent dosimeters.

C.4.2 Radiation Exposure to the Public

The information leading from normal LLNL radiation releases to public exposure and health impacts are described. This includes discussions of the radiological toxicity of releases, exposure assessments, and health risk characterization. The radiological releases from LLNL are at low levels, which result in doses that are orders of magnitude below regulatory concern.

C.4.2.1 *Radiological Toxicity*

Section C.3.1 contains a description of the basic terms describing radioactivity and its impacts on human health. A specific radionuclide's potential to result in dose to an organism is its radiotoxicity. This is typically reported as a dose conversion factor. The latter is the dose (rem) per unit intake (curies) for a specific exposure pathway. The dose conversion factor is based upon models of radionuclide movement within the body (for internal exposure). They include consideration of such factors as which organ individual nuclides are chemically/biologically attracted to, what the radiological and biological lifetimes in the body are, and the types and energies of the nuclide decay products.

Dose conversion factors are calculated for various organs of the body; e.g., adrenal, bladder, brain, and breast. Organs may be more susceptible to one nuclide or another; the classic example is the thyroid's sensitivity to iodine. The radiosensitivity of the organs and their consequences of irradiation differ; the chance of dying from thyroid cancer is less than that of cancer to other organs such as the pancreas. The effective dose equivalent weights the impacts on and effects of particular organs so that the dose from radionuclides that affect different organs can be compared on a similar (effect on whole body) risk basis. Each distinct exposure pathway; e.g., inhalation, ingestion, external exposure from contaminated ground, and air submersion, will have an associated effective dose equivalent. All of the effective dose equivalents can be summed over pathways and radionuclides to give an overall exposure and health impact. Effective dose equivalents are used everywhere in this document unless otherwise noted.

The radionuclides released during normal operations at LLNL that have the most impact on public health are tritium (from Livermore Site releases) and uranium (from Site 300). The dose conversion factors contained in the CAP88 computer model, used in the public exposure assessment for these radionuclides, are shown in Table C.4.2.1–1. Although gaseous tritium is relatively benign (being an inert gas), tritium as a component of tritiated water is relatively more toxic because water is biologically assimilated into the body easily. The dose conversion factors presented are for tritiated water. The exposure analysis assumes, as required by NESHAP (LLNL 2003z), that all of the tritium released is tritiated water. In 2002, 90 percent of the tritium released was in the form of tritiated water. References to tritium from normal operations should be assumed to be as tritiated water.

TABLE C.4.2.1–1.—*Dose Conversion Factors of Radionuclides Most Impacting Public Health From Lawrence Livermore National Laboratory Normal Operations*

Nuclide	Inhalation (rem/μCi)	Ingestion (rem/μCi)	Immersion in Air (rem/yr per μCi/m^3)	Ground Surface (rem/yr per μCi/m^2)
Tritium	1.3×10^{-4}	9.0×10^{-5}	0	0
Uranium-234	132	1.05	7.5×10^{-4}	8.5×10^{-5}
Uranium-235	122	1.00	0.75	0.017
Uranium-238	118	0.95	5.1×10^{-4}	6.4×10^{-5}

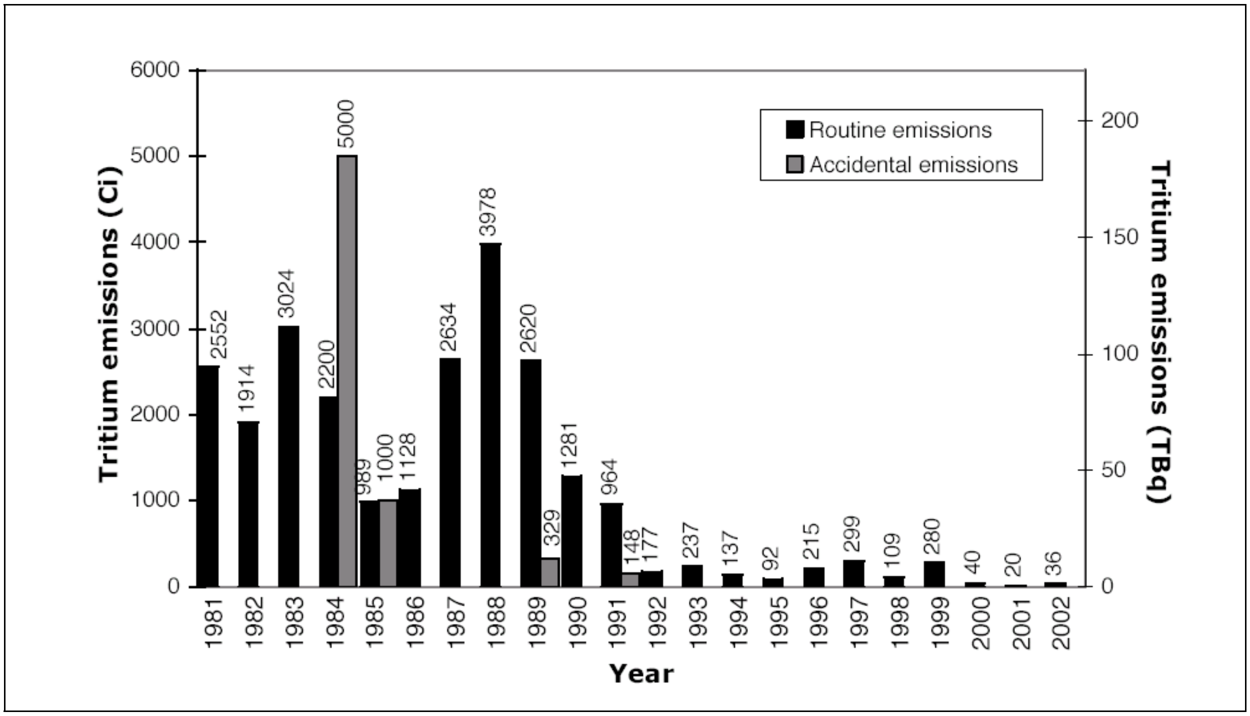
μCi = microcuries; m^2 = square meters; m^3 cubic meters; yr = year.
Source: CAP88-PC2000.

C.4.2.2 *Exposure Analysis*

An exposure analysis of 2002 releases is presented as representative of LLNL. The analysis was conducted using CAP88 (CAP88-PC2000). A more complete description of the analysis is given in the 2002 LLNL Environmental Report, Data Supplement, and the 2002 LLNL NESHAP Annual Report (LLNL 2003l, LLNL 2003z).

Sources

Small amounts of radioactivity are released into the air at the Livermore Site through stacks, vents, and diffuse releases such as soil resuspension. Tritium is the predominant radionuclide released from the Livermore Site as it relates to impacts on human health. Tritium releases have been generally decreasing over the past few years, as shown in Figure C.4.2.2–1. Table C.4.2.2–1 shows the important tritium releases from the Livermore Site. There are no measurable releases of alpha- (e.g., plutonium) and beta- (other than tritium) emitting nuclides from the Livermore Site. This is due to the use of high-efficiency particulate air filters, exhaust air systems, and other controls that prevent airborne releases of these radionuclides from operations.



Source: LLNL 2003z.

FIGURE C.4.2.2–1.—*Recent Tritium Emissions From the Tritium Facility, 1981 – 2002*

TABLE C.4.2.2–1.—*Curies of Important Radionuclides Released From Lawrence Livermore National Laboratory*

Site and Type of Radioactive Airborne Effluent Released	Curies Released Annually		
	No Action Alternative	Proposed Action	Reduced Operation Alternative
Livermore Site			
Tritium			
Building 612 yard	2	2	2
Building 331 stacks	210	210	210
Outside Building 331 (contaminated equipment awaiting storage)	1	1	1
Site 300			
Tritium	194	194	145
Uranium-234	0.0058	0.0058	0.0058
Uranium-235	0.00080	0.00080	0.0008
Uranium-238	0.062	0.062	0.062

Table C.4.2.2–1 also shows the important radionuclide releases from Site 300. Those releases would be as a result of firing table explosives experiments. The uranium isotope distribution follows that of depleted uranium, which was used in the tests. A much less important source of releases from Site 300 is contaminated soil resuspension.

Exposure Assessment

Air releases are, by far, the major potential source of public radiological exposures from LLNL operations. In contrast, normal releases to groundwater, surface water and sewerable water are not sources of direct public exposure because these waters are not directly consumed or used by the public. Unusual occurrences can lead to indirect exposure. For example, an accidental release of sewerage containing radioactivity could lead to offsite soil contamination and subsequent exposure by resuspension inhalation and soil ingestion. Apart from such unusual occurrences, radiological releases to air determine LLNL's dose to the public.

The *Clean Air Act* requires the U.S. Environmental Protection Agency to protect the public from exposure to airborne contaminants that are known to be hazardous to human health. The U.S. Environmental Protection Agency has established NESHAP to protect the public in this way. These regulations require the determination of the dose to the maximally exposed individual resulting from radionuclide emissions to air. The annual dose for this maximally exposed individual member of the public must not exceed 10 millirems per year (40 CFR Part 61). In addition, the dose caused by all pathways of release of radiation or radioactive material is limited to 100 millirems per year for prolonged exposure and 500 millirems per year for occasional exposure (DOE O 5400.5).

DOE facilities demonstrate compliance with NESHAP by using approved computer modeling procedures and environmental monitoring programs to calculate the dose to the public. Although other (non-NESHAP) procedures and programs are frequently used in NEPA analyses, such as an EIS, the use of NESHAP approved analyses in this case facilitates the merging of previously calculated (for NESHAP) doses to the public from numerous site sources into the overall impacts. The previous approved calculations were supplemented with new calculations, using the same approved procedures, for those releases which were either not previously calculated (e.g., from the NIF) or were significantly changing from the baseline year (e.g., the Tritium Facility).

CAP88 is a computer model, which has been approved by the U.S. Environmental Protection Agency, which satisfies the NESHAP requirements (CAP88-PC 2000). The program calculates the radionuclide concentrations in air as determined from operating and meteorological conditions. The air concentrations are converted to concentrations in foodstuffs that are produced and consumed by people in the surrounding area. The important LLNL exposure pathways are inhalation and ingestion of food produced in the area. External doses (i.e., immersion in air and exposure to ground surfaces) can be important contributors if the radionuclides released are strong gamma emitters. The predominant LLNL radionuclides released, tritium and uranium, are instead chiefly beta and alpha emitters, respectively.

LLNL performs the requisite dose analyses annually (LLNL 1999a, 2000h, 2001n, 2002bb, and 2003z). The analyses consider doses both to the maximally exposed individual and to the population (out to 50 miles from each site) as a whole. The 2002 maximally exposed individual for Livermore Site was located along the eastern site boundary, at the UNCLE Credit Union. At Site 300, the maximally exposed individual was located along the southern site boundary, at the Carnegie State Vehicular Recreation Area. At both sites, the maximally exposed individual was assumed to remain at the point of interest for 24 hours per day over the entire year.

The population dose from Livermore Site (dominated by tritium) is approximately one-third from ingestion and two-thirds from inhalation. The ingestion is a result of tritiated water being easily assimilated into plant matter. The population dose from Site 300 (dominated by uranium) is almost entirely from inhalation. All food consumed by the population surrounding LLNL was assumed to be grown there (with the exception of milk, for which no local production is indicated). The population (approximately 6.9 million people) distributions were centered at Livermore Site and Site 300, as applicable. The two populations overlap; a total LLNL populations dose would be the sum of the two site populations doses.

Every LLNL operation was modeled individually using the NESHAP methodology, as described above. The specific facility operating parameters; e.g., stack heights, were used. Each year's analysis considered that year's meteorology (as measured at onsite monitors) and releases. The radionuclide releases were based directly on sampling data from continuously monitored sources. For unmonitored facilities, potential annual emissions were determined from radionuclide usage inventories, time factors describing the fraction of time the nuclides were in use, and U.S. Environmental Protection Agency-determined physical state factors that describe the potential for release based on the physical state (i.e., solid, liquid, powder, or gas) of the radionuclide. Emission control abatement factors were also considered in calculating doses; each high-efficiency particulate air filter stage assumes 99 percent efficiency. For Site 300 explosives experiments, the very conservative assumption that all of the uranium involved in the experiment is aerosolized was made.

The dose to the maximally exposed individual from 2002 LLNL operations was 0.023 millirem at the Livermore Site and 0.021 millirem at Site 300. These values are less than 0.25 percent of the regulatory limit of 10 millirem. The population doses resulting from releases in 2002 from the Livermore Site and Site 300 were 0.5 and 2.5 person-rem, respectively. The population dose resulting from either site's releases was many orders of magnitude less than the population dose of approximately 2×10^6 person-rem from natural background.

The modeling results of tritium concentrations in air released from the Livermore Site are compared with site water vapor samplers. Annual average concentrations, which correspond to the annual dose, generally agree within a factor of 2.5. The modeling bias is on the high side. That is, most of the modeled concentrations are higher than the measurements; the average ratio of modeled to measured concentrations is 1.6.

Monitored Results

As discussed above, the CAP88 analysis (LLNL 2002ab) calculates the radiation dose from various environmental pathways. The offsite dose calculated from LLNL operations is very small. This is also reflected in the monitoring results.

Tritium air concentrations, as discussed above, were lower than those based on the CAP88 modeling. Accordingly, the monitored information implies an even lower dose than the small value reported from CAP88 calculations. With a normal breathing rate of 8,000 m^3/yr and the dose conversion factor from Table C.4.2.1–1, the highest Site 300 median uranium concentration resulted in only 0.03 millirem per year, 0.3 percent of the NESHAP limit.

Conservatively assuming an adult diet consisting exclusively of leafy vegetables containing the measured tritium concentration, as well as meat and milk from livestock fed on grasses contaminated with the same concentration, the maximum individual potential ingestion dose from tritium releases would be 0.011 millirem per year (LLNL 2003l). Although no health standards exist for radionuclides in wine, the highest detected concentration in Livermore Valley wines was less than one-half of one percent of the allowable California drinking water standard. The results of environmental radiation monitoring shows that the external radiation from both LLNL sites do not exceed natural background levels.

C.4.2.3 *Health Risk Characterization*

Section C.3.3 describes the factors used to estimate the health risk from exposure to radiation (dose). The dose from 2002 LLNL operations to the maximally exposed individual and to the population as a whole is discussed above. The risks of a cancer fatality to the maximally exposed individual from exposure to the LLNL operations are 1.4×10^{-8} and 1.3×10^{-8} per year of exposure at Livermore Site and Site 300, respectively. The risks of any health detriment (including nonfatal cancers and genetic effects) to the maximally exposed individual at the Livermore Site and Site 300 are 1.8×10^{-8} and 1.7×10^{-8} per year of exposure, respectively. These risks are orders of magnitude below typical levels of concern.

Health effects from population dose are described as total effects over the population. The number of fatal cancers to the populations surrounding the Livermore Site and Site 300 from the 2002 operations is calculated as 3.0×10^{-4} and 1.5×10^{-3} per year of exposure, respectively. These numbers, being much less than one, mean that it is very unlikely that LLNL releases will cause a cancer (or any health detriment) in the surrounding population.

Table C.4.2.3–1 gives the risk of a cancer fatality to the general public as a result of the No Action Alternative, Proposed Action, and Reduced Operation Alternative site actions, along with the above risks from year 2002 releases. Most of the dose is attributed to the nuclide releases indicated in Table C.4.2.2–1. Differences in Livermore MEI dose among the alternatives are a result of short-lived radionuclides released from the NIF. These short-lived radionuclides affect the MEI at the fenceline but decay prior to affecting the offsite population.

The two LLNL sites, Livermore Site and Site 300, are far enough apart that the MEI (located at each site's fenceline) from each does not affect the other. Therefore, a separate MEI is defined for each of the two sites. Similarly, separate collective doses to the population are noted for each of the two sites. Since there is overlap in the affected site populations, the population dose/risk can be summed and a composite dose/risk noted. The LLNL collective dose would be 7.0×10^{-3} person-rem for each of the three alternatives. All of the potential actions would result in a cancer risk below typical levels of concern.

TABLE C.4.2.3–1.—*Risk of Cancer Fatality to the General Public From Lawrence Livermore National Laboratory Operations*

		2002 Operations	No Action Alternative	Proposed Action	Reduced Operation Alternative
Livermore Site	MEI	1.4×10^{-8}	1.8×10^{-7}	2.0×10^{-7}	1.3×10^{-7}
	Population	3.0×10^{-4} [a]	1.1×10^{-3} [a]	1.1×10^{-3} [a]	1.1×10^{-3} [a]
Site 300	MEI	1.3×10^{-8}	3.3×10^{-8}	3.3×10^{-8}	3.3×10^{-8}
	Population	1.5×10^{-3} [a]	5.9×10^{-3} [a]	5.9×10^{-3} [a]	5.9×10^{-3} [a]

[a] Calculated value. Indicates that it is very unlikely that site releases would result in a cancer in the general population.
MEI = maximally exposed individual.

C.4.3 Exposures to Toxic Materials

As described in Appendix A, there are numerous chemicals present at LLNL. Occupational and environmental sampling and monitoring programs at LLNL provide a comprehensive assessment of actual exposure hazards present in both the workplace and the environs surrounding LLNL perimeters. Three potential pathways exist for toxic materials to leave the Livermore Site or Site 300 leading to possible public exposures. Exposure to airborne chemicals could result from emissions from current operations. Contaminated groundwater is not a result of current operations, but it could be a potential source of exposure, though currently no public wells are affected by contamination. The third pathway, exposure to chemicals released to the sewer, would be applicable only to treatment plant workers.

As discussed above, sampling and monitoring results for hazardous chemicals in air and effluents, groundwater, and sewerable discharges are below established regulatory limits and do not pose a significant hazard to members of the public.

Likewise, workplace and personnel monitoring during routine LLNL operations indicate that effective control measures have been implemented to protect workers. Personnel exposures to hazardous chemicals would be maintained as low as reasonably achievable and would not represent a significant risk to workers.

C.4.4 Environmental Exposures from Potential Accidents

Environmental exposures from previous incidents in which radioactive and nonradioactive materials were released into the environment are considered to be part of the actual releases as discussed above. Potential exposures from postulated releases and the resulting impacts are discussed in Appendix D. The chemicals examined in Appendix D were selected based on quantities of chemicals in single locations, the likelihood of an accident occurring, and the potential health effects associated with short-term (i.e., acute) exposures.

C.5 QUALITY ASSURANCE

This section presents the protocols used to ensure the quality of the ES&H programs at LLNL. It provides an account of LLNL activities and operations encompassing quality assurance and quality control. The protocols presented are limited to:

- The standards and regulations governing the quality of the ES&H programs (Section C.5.1)
- Protocols and procedures used to ensure quality in ES&H (Section C.5.2)
- Other organizations performing environmental inspections/appraisal at LLNL (Section C.5.3)

C.5.1 Regulations and Standards Pertaining to the Quality of Environment, Safety, and Health Programs

As discussed in Section C.1, the quality and maintenance of ES&H programs is addressed in the regulations and standards of several governmental agencies. Most private and governmental agencies must establish programs that comply with these requirements to ensure the protection of the workers, the public, and the environment.

Title 10 of the *Code of Federal Regulations* (CFR), Section 830.120, "Quality Assurance Requirements," (10 CFR Part 830) issued on April 5, 1994, restructured the DOE Quality Assurance Program and requires the development and implementation of a formalized Quality Assurance Program to address three areas: management, performance, and assessment. These three program areas incorporate the 10 program criteria included in both 10 CFR §830.120 and DOE O O414.1A. Title 10 applies only to nuclear facilities, which include radiological facilities. These requirements do not apply to nonnuclear facilities.

C.5.2 Protocols and Procedures Used to Ensure Quality in Environment, Safety, and Health

Quality Assurance Program

The Quality Assurance Plan, describing the Quality Assurance Program, was developed in response to DOE requirements. The Quality Assurance Program, as described in the Quality Assurance Plan, implements the rule (10 CFR §830.120) and DOE O 414.1A in accordance with the statutory and regulatory requirements identified in the LLNL Work Smart Standards. When conflicts occur between the Quality Assurance Plan and lower-tier documents, the requirements of the Quality Assurance Plan will govern (LLNL 2000i).

LLNL policy includes quality assurance in the ongoing efforts of the technical and administrative personnel at all levels and in all functions of LLNL to be effective. Quality assurance is a system of activities and processes put in place to ensure that monitoring and measurement data meet user requirements and needs. Quality control consists of procedures used to verify that prescribed standards of performance in the monitoring and measurement process are met. DOE orders and guidance mandate quality assurance requirements for environmental monitoring of DOE facilities. DOE O 5400.1 identifies quality assurance requirements for radiological effluent and surveillance monitoring and specifies that a quality assurance program consistent with the DOE order addressing quality assurance is established. This order sets forth policy, requirements, and responsibilities for the establishment and maintenance of plans and actions that ensure quality in DOE programs.

LLNL conducts quality assurance activities at the Livermore Site and Site 300 in accordance with the Environmental Protection Department Quality Assurance Management Plan, which is based on DOE O 414.1A and prescribes a risk-based, graded approach to quality assurance. This process promotes the selective application of quality assurance and management controls based on the risk associated with each activity in order to maximize effectiveness and efficiency in resource use (LLNL 2003l).

The DOE Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance requires that an environmental monitoring plan be prepared. LLNL environmental monitoring is conducted according to procedures published in Appendix A of the LLNL Environmental Monitoring Plan (LLNL 1995a).

Management dictates that all programs and line organizations use quality assurance to assist in ascertaining that LLNL's programmatic objectives are achieved with appropriate considerations for ES&H. All risks to people, property, and the environment must be reduced to levels as low as reasonably achievable. The LLNL Quality Assurance Program is intended to meet the goal of ensuring quality through existing line organizations.

The Quality Assurance Office is the LLNL primary interface to DOE on quality assurance matters and provides the point of contact for all external audits and appraisals of quality assurance activities. The associate director for plant operations appoints the manager of the Quality Assurance Office and provides the resources for staffing and operating it. This office reviews all new and revised quality assurance plans to ensure conformity with the LLNL Quality Assurance Program requirements, maintains a list of all quality assurance plans and audits, and coordinates independent appraisals of the LLNL Quality Assurance Program as directed by the associate director.

The manager of the Quality Assurance Office is responsible for preparing and revising the LLNL Quality Assurance Manual. The office also provides each directorate with the following:

- Professional guidance and advice in quality assurance methodologies, including the publication of quality assurance guides
- Assistance in developing quality assurance plans and implementing procedures
- A training and auditor-certification program for line-organization personnel in quality assurance and audit procedures
- Assistance in conducting internal audits and reviews and in coordinating external audits and reviews

Each quality assurance plan focuses on a specific activity (i.e., facilities, research activities, or development of prototype and test equipment). Activity leaders are accountable to the program leader or line manager funding the activity for the following:

- Preparing quality assurance plans and implementing procedures that ensure achievement of objectives and quality goals that are consistent with the cognizant associate director's policy

- Implementing and monitoring plans to ensure that required actions are carried out to achieve objectives and quality goals
- Promptly correcting deviations from plans and/or modifying the plans/procedures to improve effectiveness

ES&H Program Quality Assurance

Planning ES&H programs has been and remains an important aspect of LLNL operations. To plan ES&H programs, several documents have been prepared, including the ES&H Manual; the Environmental Protection Manual; facility safety plans; safety analysis reports; hazard analysis reports; safety analysis documents; integration work sheets; and hazards screening reports.

In the increased formalization being brought about by the incorporation of Integrated Safety Management, there is considerable value in collecting and organizing the ES&H documents into a formal structure and placing it under configuration control. This has been done by establishing an ES&H document structure called the ES&H Manual. Included in this new manual are the contents of the former principal ES&H document at LLNL, the Health and Safety Manual. This new ES&H Manual applies across LLNL to all operations and activities. It was structured to address all of the topics needed at LLNL and was attentive to Federal regulations, DOE orders, and the current technical capabilities. Also included are the contents of the former second principal ES&H document at LLNL, the Environmental Compliance Manual, which addressed Federal, state, and local governmental regulations. Accompanying these in the ES&H Manual are specialty manuals such as the Training Program Manual and the Quality Assurance Program. To accomplish the purpose of the ES&H Manual to have the necessary ES&H documents for LLNL activities in one structure, criteria for the specific inclusion or exclusion of candidate ES&H documents were included in the ES&H Manual (LLNL 2003k).

The requirements in the ES&H Manual are based on the Work Smart Standards identified for the specific work and associated hazards and LLNL best management practices that have been determined to be requirements. The ES&H Manual also describes the implementation of the ES&H management commitments.

Until recently, there were two types of safety documents used at LLNL, facility safety plans and operational safety plans. Both types of documents addressed ES&H concerns associated with a facility or operation. LLNL is replacing operational safety plans with Integrated Work Sheets in a phased approach as operational facility plans come due for renewal. Facility safety plans remain as key facility-specific documents and are required for hazard-ranked facilities above the classification of general industry.

Facility safety plans outline the methods for controlling and minimizing the ES&H hazards and risks identified in safety-basis reports (e.g., safety analysis reports, hazard analysis reports, or screening reports) and other ES&H evaluations for a facility. Facility safety plans should be updated whenever a change is required. At minimum, a review by the facility manager is required every 12 months to determine if changes are necessary. In addition, the facility manager will initiate a triennial full review process to renew the facility safety plan for an additional 3 years.

All work at LLNL beyond activities commonly performed by the public must be authorized with an Integrated Work Sheet. Depending on the level of hazards associated with the activity, a safety plan may be required. Integrated Work Sheets/Safety Plans are project-specific documents and are required for all Work Authorization Level C work. The requirement for a safety plan may be met by completing a safety plan form including the additional information, attaching a current operational safety plan covering the work described in the Integrated Work Sheet or attaching or referencing applicable sections of the facility safety plan covering the work described in the Integrated Work Sheet. The additional information typically addresses such issues as hazardous/radioactive material quantities, potential accidents/consequences, key ES&H limits, hazards and controls, maintenance, inspection and quality assurance, emergency response actions, and references. Every 12 months the responsible individual or his or her designee, in consultation with the ES&H Team leader or designee, reviews the Integrated Work Sheet/Safety Plan with authorized workers to determine if changes are needed. Additionally, Integrated Work Sheet/Safety Plans are renewed every 3 years and the information in the document is updated at that time as needed. The document is reviewed again and the facility point of contact, ES&H Team leader, and site managers (if applicable) re-concur on the document.

LLNL has been appraised and audited by internal and external groups to ensure that LLNL is in compliance with DOE directives and the regulations and standards of other agencies. However, a major component of the ISMS feedback and continuous improvement focus is a robust self-assessment program. Under the provisions of Contract 48, LLNL conducts an annual institutional-level self-assessment to evaluate its management performance in a number of administrative and operational areas, including ES&H. This self-assessment is made against a set of performance objectives, criteria, and measures. The self-assessment report is reviewed and verified and LLNL's performance is evaluated by NNSA and the University of California, Office of the President. LLNL also contracts with outside experts to conduct a triennial review of the ES&H Internal Review System. This review, the annual institutional-level self-assessment, Assurance Review Office evaluations, and other special reviews are accompanied by NNSA management throughout appraisals of LLNL, which include several ES&H areas (LLNL 1998d, LLNL 2003k).

In addition to the institutional assessments, LLNL has a well-developed annual self-assessment program that is specified in the ES&H Manual. These LLNL organization self-assessments evaluate the effectiveness of adherence to ES&H requirements and implemented controls at both the facility and activity levels.

C.5.3 Other Organizations Performing Environmental Inspections and Appraisals at Lawrence Livermore National Laboratory

LLNL had a total of 14 inspections in fiscal year 2002 by 7 regulatory agencies, resulting in 2 validated violations (See Table C.5.3–1). There were no additional violations from inspections in previous years. Inspections were conducted by the BAAQMD, the SJVUAPCD, the Alameda County Health Care Services Agency (Division of Environmental Protection), the Alameda County Department of Environmental Health, the Central Valley Regional Water Quality Control Board, the California Department of Toxic Substances Control, and the Livermore Water Reclamation Plant. LLNL continues to demonstrate a strong commitment to protecting the environment and meeting its regulatory commitments. The number of inspections by regulatory agencies continues to decline, indicating that regulators are becoming more comfortable with quality of the environmental program at LLNL (LLNL 2002bk).

TABLE C.5.3–1.—*Environmental Inspections and Violations in Fiscal Year 2002*

	Inspection Date	Report Date	Initial Violations	Number Contested	Validated Violations	Site
Air, 7 Inspections						
Bay Area Air Quality Management District	11/8/01	NRI	0	0	0	Livermore
	12/6/01	NRI	0	0	0	Livermore
	2/8/02	NRI	0	0	0	Livermore
	3/13/02	NRI	0	0	0	Livermore
	6/6/02	NRI	0	0	0	Livermore
	9/6/02	NRI	0	0	0	Livermore
San Joaquin Valley Unified Air Pollution Control District	6/4/02	NRI	0	0	0	300
Groundwater, 0 Inspections						
No inspections						
Natural Resources/Floodplains/Stormwater, 0 Inspections						
No inspections						
Tanks, 1 Inspection						
Alameda County Health Care Services Agency – Division of Environmental Protection	10/17/01	10/17/01	0	0	0	Livermore
Waste, 3 Inspections						
Central Valley Regional Water Quality Control Board	10/16/01	NRI	0	0	0	300
California Department of Toxic Substances Control	5/22 – 24/02 5/30/02 6/4/02	8/14/02 (final report)	4	2	2	Livermore
Alameda County Department of Environmental Health (medical waste)	9/25/02	9/25/02	0	0	0	Livermore
Wastewater, 3 Inspections						
City of Livermore Water Reclamation Plant	10/2/01, 10/8 – 9/01	12/4/01	0	0	0	Livermore
	10/15/01	11/1/01, 12/4/01	0	0	0	Livermore
	10/31/01	11/1/01, 12/4/01	0	0	0	Livermore
Hazardous Materials Transportation, 0 Inspections						
No inspections						
Total of 14 Inspections			**4**	**2**	**2**	

Source: LLNL 2002ab, LLNL 2003l.
NRI = No report issued by the agency.

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